HAMMOND

PRACTICAL SURVEYOR

LONDON
1750

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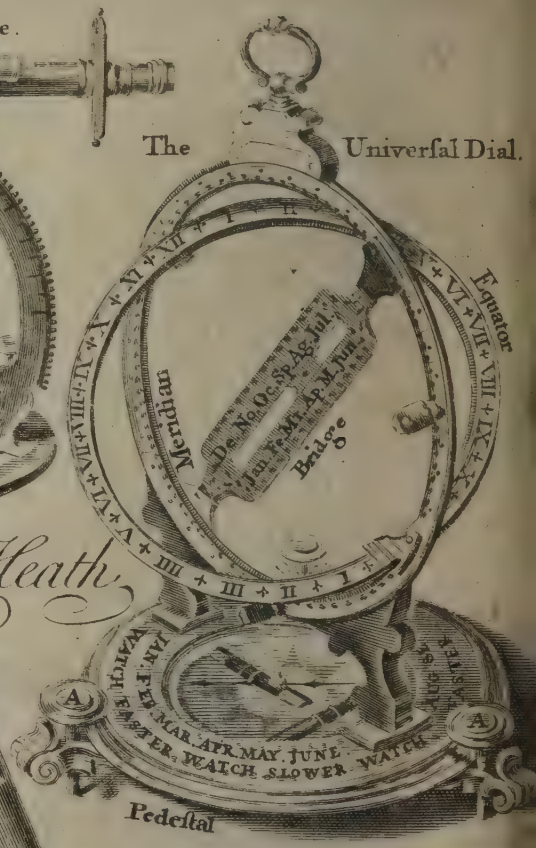
The New Improved Theodolite.

The Universal Dial.



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THE PRACTICAL SURVEYOR:

CONTAINING

The moſt approved Methods

FOR

Surveying of LANDS and WATERS,

By the ſeveral

INSTRUMENTS NOW IN USE:

Particularly exemplified with

The Common and New Theodolites.

AND ALSO

How to plot and caſt up ſuch Surveys, with the Manner of adorning the MAPS thereof.

To which are added,

Some uſes of the new Theodolite, *viz.*
In drawing the perſpective Appearance of Buildings, *&c.*
In levelling, for the conducting of Water, and
In taking the Dimenſions of ſtanding Timber.

Together with the Deſcription and Uſe of
An improved Sliding-Rule for Timber, *&c.*
An Univerſal Dial.
A Meaſuring Wheel, and
The Pantographer, for copying of Drawings.

Firſt publiſhed in part,
By *JOHN HAMMOND*;
Since enlarged,
By *SAMUEL WARNER*;
And now reviſed, corrected, and greatly augmented.

The THIRD EDITION.

LONDON:
Printed for T. HEATH, Mathematical-Inſtrument-Maker, at the *Hercules* and *Globe*, near *Exeter-Exchange* in the *Strand*.
MDCCL.

THE PREFACE.

IN the following treatiſe is contained the whole buſineſs of land ſurveying, in the manner as is now practiſed by the moſt experienced artiſts; together with ſuch problems and obſervations as are really neceſſary: And herein the ſubject is treated of in ſuch a plain, tho' conciſe manner, that the moſt common capacity, with a very little reflection, will readily conceive the whole; eſpecially if he has the inſtruments before him while he reads of their uſe: And although a great part of this work may be like what has been delivered by other writers, yet there is not one article relative to practice, but what the authors have drawn from their own experience.

The reader will here find, after ſome few introductory problems, a very particular and exact deſcription of the ſeveral inſtruments uſed in ſurveying, and a juſt compariſon of them together; particularly the various ſorts of Theodolites: With due directions and cautions in their management, according to their ſeveral kinds; in order to prevent errors and miſtakes, as well in the taking obſervations, and correcting them on the ſpot, as in plotting and laying them down in the draught.

Alſo two very large examples, being parts of actual ſurveys, containing moſt of the varieties that can happen in the practiſe of this art; the one performed by the common Theodolite, the other by the

new improved Theodolite: The manner of keeping the field-book in a diſtinct and clear method is here ſhewn; how the obſervations and meaſures are to be plotted, and the contents of the ſeveral incloſures and pieces caſt up: Alſo in the courſe of theſe two examples, and other parts of the work, there will be met with, every caution and direction that can any way contribute towards the ready diſpatch and accuracy of the practitioner, not only with regard to the field work and plotting, but alſo in the drawing, colouring, and ornamenting of the map.

The new improved Theodolite is herein explained in its parts and uſe; alſo its application to water levelling, taking of heights, and drawing in perſpective, are diſtinctly and clearly treated of.

In the account of the Meaſuring-wheel, Univerſal-dial, and Pantographer, the reader will ſee ſome particulars very uſeful and intereſting; but, as there is annexed a copious table of contents, it will be needleſs in this place to inſiſt further on any of the articles contained therein.

The major part of this work was originally compoſed by that ingenious artiſt Mr. *Samuel Cunn*; but for ſome reaſons he let it appear under the name of *John Hammond*, who was a clerk to his friend Mr. *Charles Brent*. The ſecond edition of this book was under the care of Mr. *Samuel Warner*, a perſon well known for his ſkill in the buſineſs of ſurveying; he added an appendix, containing a more particular deſcription of the Improved Theodolite, with a new method of uſing it in taking obſervations in the field; whereby an error may be more readily diſcovered and prevented than by any other way hitherto uſed; with an example of the field-book of part of an actual ſurvey taken thereby. Likewiſe a full explanation of the manner of laying down thoſe obſervations from one center, ſo as to avoid the faults which ariſe from protracting angle by angle. As alſo how to

reduce

reduce irregular figures to triangles, with the application thereof in the caſting up the contents of the forementioned example. This appendix is now put into the body of the work, part being in Section I, and of the reſt is compoſed the VIIIth Section. In the preſent edition, the former order of the ſubjects are varied, the reviſer thinking the order they now appear in to be better: But beſides this change, there are a very conſiderable variety of corrections, alterations, and additions; for the XIVth and XVIth Sections are not only added, but there are introduced into the work, many articles not in the former editions, and which were now thought very neceſſary to be communicated: Notwithſtanding which, the bulk of this book is not increaſed above the former; tho' the preſent contains near three ſheets of matter more than was in the laſt; which has been effected by making the page both broader and longer. Alſo the figures which in the former impreſſions were in four ſmall plates, indifferently deſigned, and as ill referred to, are in this brought into one plate, and rendered more uſeful.

It may be proper to obſerve, that ſome of the notions in Section XIV were drawn from a little book of *Martin Maſter*, publiſhed in 1661: And part of the XVIth Section, is a tranſlation from a *French* piece publiſhed by *C. Langlois*, an engineer to the *French* King, who pretends to no more than to have perfected an inſtrument of this kind already known; and, indeed, among the inſtruments of Sir *Jonas Moore*, ſuch a one was found, but ſomewhat more antique and inconvenient than that which is now propoſed: But M. *Langlois* not having given a table of the lengths of the ſeveral diviſions from their reſpective centers, nor how they are to be found, it was thought proper to add theſe articles to compleat the account of the Pantographer.

Feb. 18, 1749-50.

J. R.

Note,

Note. The enſuing directions having been omitted in their proper places, it was thought convenient to annex them in this place.

In the beginning of the field-book it will be proper to write ſome ſuch title as the following——

The field-book, containing obſervations and dimenſions taken in the ſurvey of the manor of—— in the pariſh of—— in the county of——; belonging to——: Surveyed in the months of —— in the year——by——and the following aſſiſtants, *viz.*
A. B. of the pariſh of——labourer.
C. D. ——
&c.
Specifying their names, places of abode and occupation; and at the beginning of each day, write the day's name, day of the month and hour; alſo at the end of each day's work write the hour; and, if there ſhould be occaſion to change any of the aſſiſtants, or have new ones, let this be alſo inſerted, with the day: For ſuch obſervations may be of ſervice, in caſe the ſurveyor ſhould, on any account relating to the premiſes, be called on to give his teſtimony.

In drawing out the Terrier of a ſurvey, a diſpoſition, ſomewhat like the following, may be found convenient. In ſix columns, titled N°, Kind, Names, Proprietors, Tenants, Quantity; write

1*ſt*, The number refered to in the map, if the ſeveral pieces therein are numbered.

2*d*, The kind, whether arable, paſture, meadow, wood, garden, houſes, yards, water, *&c.*

3*d*, The name that the piece is known by.

4*th*, The name of the lord of the manor, or other perſon, to whom the piece belongs, whether in fee-ſimple or copy-hold.

5*th*, The name of the tenant who rents, or occupies the piece.

6*th*, The quantity that piece contains, in acres, rods, and poles.

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The

THE *Practical Surveyor.*

SECT. I.

Of MENSURATION *in general, with the moſt neceſſary* GEOMETRICAL PROBLEMS.

TO Meaſure, in the general ſenſe that *Geometricians* uſe the word, is, to aſſume any certain Quantity, and expreſs the proportion which other ſimilar Quantities bear thereto: But in the common acceptation, to Meaſure, is, to apply ſome certain known quantity pitched upon for a ſtandard, and thereby to determine the preciſe extent, quantity or capacity of any thing of the ſame kind. Thus:

The meaſure of a line is found by applying the linear Inch, Foot, Yard, Pole, *&c.* to that line, in

order to discover its length; the doing of which is called *Longimetry*.

The Measure of a superficies is obtained by the application of the superficial or square Inch, Foot, Yard, Pole, Acre, *&c.* thereby to determine its Area or Content; the method of doing which is called *Planimetry*, whereof Surveying of land is a part; and of this the following pages chiefly treat.

The Measure of a Solid is had by comparing it with the solid or cubic Inch, Foot, Yard, Gallon, *&c.* thereby to find its capacity or solid content, which is called *Stereometry*, and comprehends the measuring of Timber, Stone, *&c.*

Now, though it cannot be supposed that any Person, who is wholly ignorant of the first principles of *Geometry*, should expect to become a compleat Surveyor by barely reading this Book, whence it might seem altogether unnecessary to insert the common Definitions and Problems; yet, in order to refresh the reader's memory, when other books are not at hand, it was thought not improper to lay down some few of the most popular *Problems*; and such are those that follow.

PROB. I.

Upon a given right line, to erect another right line, which ſhall be perpendicular to the right line given.

THE right line given is AB (*Fig.* 1.) upon which, from the point E it is required to erect the Perpendicular EH.

Opening your Compaſſes at pleaſure to any convenient diſtance, place one foot in the aſſigned point E, and with the other make the marks C and D, equi-diſtant on each ſide the given point E. Then opening your Compaſſes again to any other convenient diſtance, wider than the former, place one foot in C, and with the other deſcribe the Arch GG; alſo (the Compaſſes remaining at the ſame diſtance) place one Foot in the point D, and with the other deſcribe the Arch FF: Then from the point H, where theſe two Arches interſect or cut each other, draw the right line HE, and it will be a Perpendicular to the given right line AB; which was the thing required to be done.

PROB. II.

To erect a Perpendicular upon the End of a right Line given.

LET AB (*Fig.* 2.) be a right Line given, and from the End thereof, at B, let it be required to erect the Perpendicular BF.

Firſt, Your compaſſes being opened at any convenient Diſtance, place one foot in B, and with the other make the mark C; the Compaſs point reſting in C, with the other foot make the mark D, in the given line AB; lay a Ruler from D to C, and draw the line DE, making CE equal to CD. *Laſtly*, from B, through E, draw the line BF, which will be the Perpendicular required.

PROB. III.

To divide a given right Line into Two equal Parts.

LET CB (*Fig.* 3.) be a right line given, to be divided into two equal Parts.

From the extremes B and C, with any diſtance greater than half the given line, deſcribe the arches above and below, cutting one another in the points D and F: Draw DF, and it will divide AB into two equal parts in H, as required.

PROB. IV.

To let fall a Perpendicular from any Point aſſigned, upon a right line given.

LET the point given (*Fig.* 4.) be C, from which point it is required to draw a right line, which ſhl be perpendicular to the given right line AB.

Firſt, From the given point C, to the line AB, draw an occult line at pleaſure, as CE, which divide into two equal parts in the point D: Then placing one foot of the compaſſes on the point D, with the diſtance DC, deſcribe the Semicircle CFE, cutting the given line AB in the point F. *Laſtly*, From the point C, draw the right Line CF, and it ſhall be the perpendicular to the given line AB, which was required.

PROB. V.

To make an Angle equal to an Angle given.

LET the Angle given be ACB *(Fig. 5.)* and let it be required to make another Angle equal thereunto.

Firſt, Draw the line EF at pleaſure; then on the angular point C, as a center, with any convenient diſtance deſcribe the arc AB, between the legs of the angle given; alſo upon the point F, with the ſame diſtance deſcribe the arc DE: Then take with your compaſſes the diſtance AB, and ſet the ſame diſtance from E to D. *Laſtly*, Draw the line FD, ſo ſhall the angle DFE be equal to the given angle ACB.

PROB. VI.

At a given Diſtance, to draw a right Line parallel to a right Line given.

LET the line given be AB, *(Fig. 6.)* unto which it is required to draw another right line parallel, at the diſtance MN.

Firſt, Open your compaſſes to the diſtance MN, then placing one foot in A, with the other deſcribe the arc C; alſo place one foot in B, and with the other deſcribe the arc D. *Laſtly*, Draw the line CD, ſo that it may only touch the arcs C and D; ſo ſhall the line CD be parallel to the line AB, and at the diſtance MN, as was required.

PROB. VII.

A right line being given, to draw another right line parallel thereunto, which ſhall alſo paſs through a point aſſigned.

LET AB (*Fig.* 7.) be a line given, and let it be required to draw another line parallel thereunto, which ſhall paſs through the given point C.

Firſt, Take with your compaſſes the diſtance from A to C, and placing one foot thereof in B, with the other deſcribe the Arc DE; then take in your compaſſes the diſtance AB, and placing one foot in the point C, with the other deſcribe the Arc FH, croſſing the former Arc DE in the point H. *Laſtly*, Draw the line CH, and it ſhall be parallel to AB.

Theſe two laſt PROBLEMS *may be more eaſily performed by a parallel Ruler.*

PROB. VIII.

To divide a given right line into any number of equal parts.

LET AB (*Fig.* 8.) be a right line given, and let it be required to divide the ſame into five equal parts.

Firſt, From the end A of the given line, draw the line AC, making any angle; then from the other end B of the given line, draw the line BD parallel to AC, (or make the angle ABD equal to the angle CAB) then upon the lines AC and BD, ſet off any four equal parts (which is one leſs than the number of parts into which the line is to be divided) on each line, as 1, 2, 3, 4; then draw lines from 1 to 4, from 2 to 3, from 3 to 2, and from 4 to 1, which lines, croſſing the given line AB, ſhall divide it into five equal parts, as was required.

PROB.

PROB. IX.

Any three right lines being given, provided the two ſhorteſt taken together be longer than the third, to make thereof a Triangle.

LET it be required to make a Triangle of the three lines C, B, and A, (*Fig.* 9.) the two ſhorteſt whereof, *viz.* C and B taken together, are longer than the third line A.

Firſt, Draw the line DE equal to the given line B, then take with your compaſſes the line A, and ſetting one foot in E, with the other deſcribe the Arch HG; alſo take the given line C in your compaſſes, and placing one foot in D, with the other deſcribe the Arch KF, cutting the former Arch HG in the point O: *Laſtly*, If from the point O, you draw the lines OE and OD, there will be formed the Triangle ODE, whoſe ſides ſhall be equal to the three given lines A, B, C.

In like manner, a Triangle *lmn* may be made equal to another given Triangle LMN. See *Fig.* 10.

Alſo any rectilineal figure *abcdefg*, is made equal to any other rectilineal Figure ABCDEFG, by making the Triangles *abg*, *bgf*, *bfe*, *bce*, *ced*, reſpectively equal to the Triangles ABG, BGF, BFE, BCE, CED. See *Fig.* 11.

PROB. X.*

To reduce any irregular Figure into a Triangle.

By this Problem the content of any irregular piece of land may be caſt up much ſooner and more accurately than by the common method of dividing it into Trapezia and Triangles.

THE practice hereof depends wholly on the 37th Prop. of the 1ſt Book of *Euclid*, where it is demonſtrated, that Triangles ſtanding on the ſame baſe, and being between the ſame parallels are equal one to the other.

EXAMPLE I.

Let it be required to reduce the Trapezium ABCD, *Fig.* 12. into a Triangle, having its Vertex at the Angle A.

Produce the baſe BC, and draw the diagonal AC, thro' D draw DE parallel to AC, till it meet BC in E, join AE and ABE will be the Triangle required.

Fig. 13. ſhews how in like manner to reduce a Trapezium having a re-entring angle.

EXAMPLE II.

Let it be required to reduce the Trapezium ABCD, *Fig.* 14. to a Triangle whoſe vertex ſhall be at the point E in one of the ſides AD.

Join BE and CE, draw AF parallel to BE, and DG parallel to CE, till they meet the baſe BC produced in F and G, draw the lines EF and EG, and the triangle FEG will be equal to the Trapezium given.

* This Problem and it's Examples, are a Part of Mr. *Warner*'s Appendix to the laſt Impreſſion of this Work.

EX-

EXAMPLE III.

Let it be required to reduce the Pentagon ABCDE, *Fig.* 15. to a Triangle, having its vertex at the Angle A.

Produce the baſe CD both ways, and draw the Diagonals AC, AD: Through B draw BF parallel to AC to cut CD in F, and through E draw EG parallel to AD to cut CD in G, join AF and AG, and AFG will be the Triangle ſought.

EXAMPLE IV.

Let it be required to make a Triangle equal to the irregular Hexagon ABCDEF, and let the ſide AB be one ſide of the triangle *Fig.* 16.

Produce the ſide DE, join AE, and parallel thereto thro' F draw FH to meet DE in H; join BD, and parallel thereto draw CG to meet DE in G; by B and G draw out a right Line; join AG, and parallel thereto thro' H draw HI to meet BG produced in I, draw AI, and ABI will be the triangle required.

EXAMPLE V.

To reduce any right-lined Figure given into a Triangle; as ſuppoſe the ſeven-ſided Figure ABCDEFG, *Fig.* 17.

Firſt draw BD, and its parallel CK; then if BK be drawn, it will cut off from the Figure the triangle DKS, and will take in the triangle BCS equal thereto, and the ſide BK will ſupply the uſe of the two ſides BC and CD. Alſo, draw GE, and its parallel FL; then if GL be drawn, it will cut off from the figure the triangle LRE, and take in the triangle GRF equal thereto, and the Side GL will ſupply the uſe of the other two ſides GF and FE, and the whole Plot ABCDEFG conſiſting of ſeven ſides, is reduced

duced to the five-ſided figure ABKLG, yet ſtill retaining the ſame quantity. Now to reduce this plot into a triangle, work in all reſpects as in the *Third Example*. Firſt, produce the Baſe both ways, then draw the lines AK and AL ; and parallel to them the lines BH and GM, cutting DE extended in H and M. Laſtly, draw the lines AH, AM, and they will conſtitute the triangle AHM equal to the right-lined figure given.

In like manner may any other irregular figure of ever ſo many ſides be reduced to a triangle, and that very readily by uſing a parallel Ruler, whereby we avoid drawing the unneceſſary lines, only marking their interſections on the baſe. Thus in *Fig.* 18. lay the edge of a parallel Ruler to the points B and D, then open the Ruler till the ſame edge cuts the point C, and mark where it interſects the baſe DE at k ; lay the Ruler again to the points k and A, transfer it to B, and mark its interſection on the baſe at h ; then draw A h, which will be one ſide of the Triangle ſought. Again, laying the Ruler to E and G, tranſfer it to F, and mark the interſection on the baſe at l, lay the Ruler to l and A, and mark where its parallel edge by G interſects the baſe prolonged at m. Laſtly, draw A m, and the Triangle A h m will be equal to the ſeven-ſided figure as was required.

SECT. II.

Of INSTRUMENTS *uſed in Surveying Land.*

INSTRUMENTS uſed in Surveying are, either to meaſure, or lay down the lengths of lines, or their poſitions.

The moſt proper inſtruments for meaſuring lengths, in Towns, Streets, or any other Buildings, are 5 Foot and 10 Foot Rods, and a Chain of 50 Foot long; for Fields and Woods, a Chain, which from its contriver is uſually called *Gunter*'s *Chain*, and is in length 66 Foot or 4 Poles, conſiſting of 100 Links, each containing 7 Inches and $\frac{92}{100}$; and a Rod, called an *Offset-Staff*, whoſe length is equal to $\frac{1}{10}$ part of the Chain, that is, 10 Links, or 6 Foot 7 Inches and $\frac{8}{10}$, tho' ſometimes this Rod is 15 Links in length, or 9 Foot 10 Inches and $\frac{8}{10}$.

The Wheel is uſed with moſt advantage in meaſuring of Roads.

The Inſtruments uſed for taking the Poſitions of lines are of two kinds.

With ſome we take the Poſition of a line, by the Angle which that line makes with the Meridian, uſing a Box and Needle; as with the *Theodolite*, the *Semi-Circle*, the *Circumferentor*, the *Plain-Table*, the *Perambulator*, the *Peractor*, &c. and this is uſually called the *Bearing of the Line*.

With others we take the poſition by the angle that the line makes with any other given line in poſition; as with the limb of the *Theodolite*, the limb of

of the *Semicircle*, the frame of the *Plain-Table*, the *Bevel*, the *Chain*, or *Rods*.

All other inſtruments either differ from theſe only in their names, or elſe are contained in them.

But with ſome of theſe inſtruments, very conveniently we take the poſition in both caſes, at one obſervation; as with the *Theodolite*, the *Semi-circle*, or the *Plain Table*.

With ſome of theſe inſtruments we take the angle itſelf, as with the *Bevel*, or with the *Plain Table* cover'd with a ſheet of paper; and with others, we expreſs the relative quantity of that angle by numbers. So when we uſe the chain, we expreſs the angle by Sextants, Links, and tenth parts of a Link; when we uſe Rods, we expreſs it by Sextants, and centeſimal parts of a rod; and when we uſe other inſtruments, we expreſs the angles by degrees and minutes.

We may alſo obſerve, that of *Theodolites* and *Semicircles* there are various kinds; in ſome the Box and Needle is fix'd to the Plate, in others to the Index. And the working with each of theſe varies according to the manner of their Numbering.

As for Roads, the Wheel with its Indices, ſhewing the diſtance, and its box and needle with ſights ſhewing its bearing or poſition in reſpect of the Meridian, is an inſtrument ſpeedy and ſufficiently exact: provided we reject the breadth of the road, and only regard the bearing and length.

Laſtly,

Laſtly, Inſtruments for plotting, are a ſcale decimally divided the whole length, cloſe to both the edges ; and at every tenth diviſion numbered 0, 1, 2, 3, 4, *&c.* denoting Chains ; the Numbering ſo ordered that we may count either from the Right to the Left, or from the Left to the Right ; and a *Protractor* always to be divided, numbered, and fitted according to your inſtrument.

Thus, all *Circumferentors* (either abſolutely ſuch, or only uſed as ſuch, *viz.* when contained in the *Theodolite*, *Semicircle*, or *Plain Table*) let the numbers in the *Protractor* increaſe contrary to thoſe in the box ; but when the box and needle takes the bearing, as the *Peractor* or *Perambulator* doth, the numbers of the *Protractor* muſt increaſe as thoſe in the box.

And for the limbs of all *Theodolites*, *Semicircles*, and *Plain Tables*, if the circuit be made {according / contrary} to the numbers on the limb, the numbers of the *Protractor* moſt conveniently increaſe the {contrary / ſame} way with the numbers on the limb of the inſtrument, and this ſuppoſing the eye in the center.

SECT.

SECT. III.

To obſerve the Poſition of a Line by any of the preceding Inſtruments.

I. *By the* Circumferentor.

THE Box of the *Circumferentor* is divided into 360 degrees, and numbered in 4 quarters, from the North and South both to the Eaſt and Weſt, by the figures 10, 20, 30, 40, 50, 60, 70, 80, 90; but theſe diviſions are alſo numbered from the North towards the Eaſt or Weſt, all round, till they end at the North again; by the figures 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, and ſo on to 360. Of theſe two ways of numbering, the latter is properly the *Circumferentor*, and the former the traverſing Quadrants or Quarters.

Now, if it be required to obſerve the bearing of the line AB (*Fig.* 19.) the Inſtrument ſtanding at A; the Flower-de-luce in the Box being towards you, direct the Sights to B; and the South end of the Needle will point at 207 Degrees in the *Circumferentor*, and at S. W. 27, in the traverſing Quadrants.

And if you were going round the Field, and ſo next to obſerve the bearing of the Line BC; at B turn the Index about, the Flower-de-luce being towards you, till thro' the Sights you ſee the hair cut C: Then will the South end of the Needle point at

111, in the *Circumferentor*, (which is the bearing always counted from the North, and in these Examples from the North to the Eastward) and at S. E. 69 in the traversing Quadrants, which is the bearing always counted from the North or South towards the East or West. Here we may note, that the bearing taken with the *Circumferentor* may be any number of degrees not exceeding 360, but that with the traversing Quadrants never exceeds ninety degrees.

When you suspect the Needle does not play well; direct the Index to your mark, and note, in a waste piece of paper, the degrees pointed at by the Needle; then with a clean Knife, or a Key, or any other polished bit of Steel, which has touched a Loadstone, move the Needle, by applying it to the Box, and when it hath settled again, examine what degree it then points at, your Index being still directed to the preceding mark; and if the degrees are the same, they may be entered into the Field-Book; but if not, the Cap and Pin must be cleansed with some brown paper and a little Puttey or Whiting, and thereby freed of such dust or dampness as hath gotten to it; if, after all, the Needle doth not play freely, screw in a new Pin, or use another Needle, or do both. These Necessaries every Surveyor ought to have in his pocket while he is in the Field.

If you suspect an error in the bearing of any line already taken, arising from the Needle's being acted on by some hidden Magnetic power, or from your own mistake in observing the degrees pointed at; the doubt may be cleared, and the error corrected at the next station; thus,

Having come to B (*Fig.* 19.) the Flower-de-luce being from you, look back to A, and then will the South end of the Needle point at 207 degrees in the

the *Circumferentor* and at S. W. 27 degrees in the traverſing quadrants; juſt as it did at A.

Laſtly, if you have no reaſon to ſuſpect the Needle, and it is moſt convenient to plot by it, the ſpeedieſt way is to place the inſtrument only at every other Angle, and there to take the bearing of the two lines which form that angle.

So, if you would obſerve the bearings of the lines of *Fig.* 19. firſt place the inſtrument at B, and with the Flower-de-luce from you, direct the ſights back to A, ſo the South end of the Needle will point at 207 degrees in the *Circumferentor*, and at S. W. 27 degrees in the traverſing quadrants, which is the bearing of AB; then with the Flower-de-luce next you, direct the ſights to C, ſo the South end of the Needle will point at 111 degrees in the *Circumferentor*, and at S. E. 69 degrees in the traverſing quadrants, which is the bearing of BC.

Now place the Inſtrument at D, the Flower-de-luce being from you, direct the ſights back to C, ſo the South end of the Needle will point at 44 deg. 30 Min. in the *Circumferentor*, and at N. E. 44 deg. 30 Min. in the traverſing quadrants, which is the bearing of CD; and directing the ſights to E, the Flower-de-luce being towards you, the South end of the Needle will point at 102 Degrees 15 Minutes in the *Circumferentor*, and at S. E. 47 Degrees 45 Minutes in the traverſing Quadrants.

In like manner work at F, *&c.* always keeping the Flower-de-luce from you when you look backwards, and towards you when you look forwards; ſo will the South end of the Needle point at the Degrees of the Bearing in both Caſes.

To protract any line whoſe bearing is taken by the Circumferentor.

FIRST, draw lines parallel to one another quite thro' the deſigned draught, at diſtances not exceeding the breadth of the diametrical part of your *Protractor*, as in *Fig.* 19. and mark them with *N.* and *S.* for north and ſouth; then lay the center of the *Protractor* on A, the point given repreſenting the ſtation A in the field, and, by help of the diviſions continued beyond the ends of the diameter of the *Protractor*, lay the diameter parallel to thoſe north and ſouth lines; and if the *Protractor* be only a *Semicircle*, lay the beginning of the numbering northwards, when the degrees are fewer than 180, but ſouthwards when more: The *Protractor* being thus placed, make a mark cloſe to the limb againſt 207, the degrees of the bearing, and thro' it draw the line AB; and ſo will AB have a bearing like to that, which you obſerved the line AB to have in the field. In like manner you may lay down the bearing of any other line, as BC; if you obſerve to lay the beginning of the numbering northwards, when the degrees are leſs than 180, and ſouthwards when more: But if the *Protractor* be a whole circle, there will be no occaſion for turning the beginning of the numbers, which may always be northwards.

And if you would lay down the bearing of any line AB, *Fig.* 19. from any aſſigned point A, with the traverſing quadrants; after you have drawn north and ſouth lines as before, the north being upwards, write eaſt on the right hand ſide of the map, and weſt on the left. Now lay the center of the *Protractor* and diameter as before ſhewn; ſave that inſtead of obſerving the number of the degrees, you turn the limb of the *Protractor* eaſt-

ward, when the bearing is N. E. or S. E. and weſtward, when it is N. W. or S. W.

The *Protractor* being thus placed, againſt S. W. 27. make a mark, and thro' it draw the line AB, and ſo will AB have a bearing like to that which AB was obſerved to have in the field. In like manner you may lay down the bearing of any other line.

II. *To obſerve with a* Theodolite, *both by the Limb, and by the Box and Needle.*

BEFORE you engage in a ſurvey, you ought to conſider the numbering of your inſtrument; thus, when the eye is conceived to be placed in the center, conſider whether the numbers increaſe from the left to the right; or from the right to the left; or, according to the farmer's familiar phraſe, whether the numbers increaſe with or againſt the ſun's motion.

And then obſerve, that with a *Theodolite*, whoſe box is fixed to the plate, the circuit is moſt conveniently made with the increaſing of the numbers; and the fixed ſights ſhall always be directed to the next ſtation, and the index to the laſt. But when the box is fixed to the index, 'tis beſt to go round contrary to the order of the numbers; and then the fixed ſights are to be directed to the laſt ſtation, and the index to the next.

And if the beginning of the degrees are kept towards you when the fixed ſights are directed, and the Flower-de luce towards you when the index is directed; the degres cut by the end of the index which is next you, are thoſe which meaſure the angle; and the degrees pointed at in the box by the ſouth end of the needle, give the bearing of the next length. And this bearing will be, in all reſpects, the ſame with that taken by the *Circumferentor*;

tor; provided that the box be divided and numbered like that of the *Circumferentor*.

This double obſervation is of great uſe to the ſurveyor; for hereby he may either plot by the angle, or the bearing, or by both, as he ſhall find moſt convenient; and alſo, may prove his obſervation before he moves the inſtrument. For, of the numbers expreſſing the bearing of the lines forming any angle, if the leſſer be ſubtracted from the greater, and the remainder be increaſed by 180 degrees when leſs than 180, or, if greater than 180, is diminiſhed by 180; the reſult in either caſe will give the angle itſelf, or its ſupplement to 360 degrees.

When a *Theodolite* is uſed with a box fixed to the plate, and the numbers in the box increaſe the ſame way with the numbers on the plate; or, which comes to the ſame, with the box fixed to the index, and the numbers therein increaſe the contrary way with the numbers on the plate (moſt *Theodolites* being made one of theſe ways, or ſhould be ſo to be moſt convenient); then a *Protractor* being numbered contrary to the numbers in the box, will be fitted to lay down the plan, either according to the angles taken by the limb, or by the bearing taken with the needle, or by both together, in order to prove the truth of each other: And then alſo may the truth of the angle or bearing be proved, before the inſtrument is moved from the ſtation by either of the two following rules.

If to the preſent bearing be added 180 degrees, and from the ſum you ſubtract the laſt bearing; then the remainder will be the preſent angle.

And if to the preſent angle you add the laſt bearing, and from the ſum ſubtract 180; then will the remainder will be the preſent bearing.

But if the degrees to be ſubtracted are more than thoſe from which they are to be ſubtracted; the latter muſt be increaſed by 360, and then ſubtract.

And if the remainder be more than 360, then abate 360, and the reſult gives the degrees required.

So, with a *Theodolite* that hath the box fixed to the index, and the eye being conceived in the center, the numbers on the plate increaſe from the left to the right, but thoſe in the box the contrary way, and ſo moſt proper to work againſt the ſun: If you would take the bearings of the lines of *Fig.* 19. beginning from any aſſigned angle, ſuppoſe A; then your inſtrument being planted at A, direct the index to the next ſtation at B, and the ſouth end of the needle will point at 207 degrees in the *Circumferentor*. And for the following angles and bearings, when the

inſtrument is planted at { B C D E F G } direct the fix'd ſights to { A B C D E F }

and there ſcrew the inſtrument faſt; then direct the index to { C D E F G A }

	°	′
and the end of the index next your eye will cut on the limb the angles	84.	00
	113.	30
	237.	45
	49.	35
	102.	40
	234.	00

and

	°	′
and the south end of the needle will, as in the *Circumferentor*, point at	111.	00
	44.	30
	102.	15
	331.	50
	254.	30
	308.	30

And with a *Theodolite*, that hath the box fixed to the index, and the numbers of the plate contrary to those of the box, while the eye is conceived placed in the center, increase from the right to the left, and so most proper to work according to the sun's motion; if you would take the angles and the bearings of the lines of *Fig.* 19. and begin from any assigned angle, suppose A; then your instrument being planted at A, direct the index to the next station G, and the south end of the needle will point at 231° 30′ in the *Circumferentor*. And for all the following angles and bearings, when the

instrument is planted at	G	direct the fix'd sights to	A
	F		G
	E		F
	D		E
	C		D
	B		C

and there screw the instrument fast; then direct the index to

F	
E	
D	
C	
B	
A	

	°	′
and the End of the index next the eye will cut on the limb the angle - - - - - - - - - - -	234.	00
	102.	40
	49.	35
	237.	45
	113.	30
	84.	00

	°	′
and the ſouth end of the needle, as in	285.	30
the *Circumferentor*, will point to the	208.	10
bearing - - - - -	77.	45
	135.	30
	69.	00
	333.	00

But with a *Theodolite* that hath the box fixed to the plate, and the numbers on the plate as well as thoſe in the box (the eye being placed in the center) increaſe from the right to the left; and therefore moſt proper to work contrary to the ſun's motion; if you would take the angles and the bearings of the lines of *Fig.* 19. and begin at an aſſigned angle A; then your inſtrument being planted at A, direct the fixed ſights to B, and the ſouth end of the needle will point at 207° 00′, as in the *Circumferentor*, and as in the firſt example. And for all the following angles and bearings, when the inſtrument is planted at { B C D E F G } direct the fixed ſights to { C D E F G A }

then ſcrew the inſtrument faſt, and direct the Index to - - - - - { A B C D E F }

	°	′
ſo will the end of the index next the	84.	00
eye cut on the limb the angle	113.	30
	237.	45
	49.	35
	102.	40
	234.	00

and

	°	′
and the ſouth end of the needle, as	111.	00
in the *Circumferentor*, will point at	44.	30
the bearings - - - - -	102.	15
	331.	50
	254.	30
	308.	30

both as in the firſt example.

Alſo with a *Theodolite*, that hath the box fixed to the plate, and the numbers on the plate, as well as thoſe in the box, the eye placed in the center, increaſe from the left to the right, and therefore moſt proper to work according to the ſun's motion; if you would take the angles and the bearings of the lines *Fig.* 19. and begin at an aſſigned angle at A, direct the fixed ſights to G, and the ſouth end of the needle will point at 231° 30′ as in the ſecond example. And for all the following angles and bearings, when

the inſtrument is planted at	G F E D C B	direct the fixed ſights to	F E D C B A

then ſcrew the inſtrument faſt, and direct the index to - - - -	A G F E D C	

	°	′
and ſo will the end of the index next	234.	00
the eye cut on the limb, the angle	102.	40
	49.	35
	237.	45
	113.	30
	84.	00

and the ſouth end of the needle, as in the *Circumferentor*, will point at the bearings - - - - .

°	′
285.	30
208.	10
77.	45
135.	30
69.	00
333.	00

both as in the ſecond example.

With either of theſe four inſtruments, the angles and the bearings of the Lines are taken, at once ſetting the index, as eaſily and expeditiouſly as the angle itſelf only; which evidently appears from the four preceding examples. And the truth of theſe obſervations may be readily proved by either of the rules already laid down.

For, the inſtrument being planted at B, in the firſt and third examples, if to 111° 00′ the bearing there taken, you add 180° 00′ and from the ſum 291° 00′, take the laſt bearing 207° 00′, there will remain 84° 00′, which gives the angle taken at B, exactly as there obſerved; and proves the angle and theſe two bearings to have been truly obſerved.

In like manner, the inſtrument being planted at C, in the ſame examples; if to the bearing there taken, 44° 30′, you add 180° 00′, and from the ſum 224° 30′, you ſubtract 111° 00′, the bearing taken at the laſt ſtation; the remainder 113° 30′ gives the angle at C exactly as it was there obſerved; which proves that the angle, and alſo the laſt and preſent bearings are truly obſerved.

Alſo the inſtrument being planted at D; if to the bearing there taken 102° 15′, you add 180° 00′, and from the ſum 282° 15′, take 44° 30′ the laſt bearing; the remainder 237° 45′ gives the angle at D, as there obſerved.

But the inſtrument being planted at E, if to the bearing there taken, 331° 50′, you add 180° 00′, and from the ſum 511° 50′ you ſubtract 102° 15′, the

the laſt bearing; the remainder 409° 35′ leſſen'd by 360°, becauſe greater than 360, gives 49° 35′, the angle at E. And ſo of all the reſt.

And in like manner may the angles and bearings be compared in the ſecond and fourth examples.

Or the angles and bearings may be compared by the ſecond rule thus: The Inſtrument being planted at B, if to 84° 00′, the preſent angle, you add 207° 00′, the laſt bearing, and from the ſum 291° 00′ you take 180° 00′, the remainder 111° 00″, gives the preſent bearing, as obſerved.

The angles and bearings being truly taken, it remains to ſhew how

To plott, and therein to diſcover and correct an error before it is communicated to the following part of the work.

HAving provided yourſelf with a *Protractor*, whoſe numbers increaſe contrary to thoſe in the box, draw acroſs your deſigned draught parallel lines, as in plotting obſervations taken with the *Circumferentor*.

Then having choſe a convenient point to repreſent the firſt ſtation, as at A, from thence, working by the firſt or third examples, lay down the bearing 207° 00′, and draw AB, as ſhewn in plotting from the *Circumferentor*. On the point B lay the center of the *Protractor*, and its diameter on the line AB produced both ways, if neceſſary, ſo that the beginning of the degrees may be towards the laſt ſtation, if the angle be leſs than 180°, but the contrary way, if greater; and cloſe to the edge of the *Protractor* make a mark againſt 84° 00′, the degrees of the angle B, and draw BC. Turn the *Protractor* about on its center, till the diameter be parallel to the meridians, the beginning of the degrees being towards the north, when the bearing is

leſs than 180° ; but contrarywiſe when more ; and if the line BC cut the bearing 111° 00′ on the edge of the *Protractor*, that line is truly laid down ; but not ſo, if it cut any where elſe.

But working according to the ſecond and fourth examples, lay down the bearing 231° 30′, and draw AG : On the point G lay the center of the *Protractor*, as before ſhewn, its diameter coinciding with the line AG, and mark off the angle G, 234° 0′, draw GF : Turn the *Protractor*, as before, and if FG cut 285° 30′ on the *Protractor's* edge, the line is truly laid down.

In like manner, may any other angle be examined, and if found erroneous, the error may be corrected, before it is communicated to the following part of the work.

And we may obſerve, that, if the plot be laid down by the bearings of the lines, thoſe bearings may be examined by meaſuring the angles as ſoon as plotted.

Though this method ſufficiently recommends itſelf, both in reſpect of diſpatch as well as accuracy ; I do not expect it will be practiſed by any but the unprejudiced. For he who hath ſurveyed much land with a *Circumferentor* alone, or with a *Semicircle* or *Theodolite*, without a needle, or with any other inſtrument, that doth not afford a double obſervation ; he I ſay, hath not provided a check to his frailty, and will ſcarce forſake his old way, becauſe he will not accuſe himſelf.

There are two other ways to uſe theſe *Theodolites*, each equally exact with the former, but not ſo expeditious. One way is to take the bearing with the traverſing quadrants ; the other is to take the bearing with the degrees on the limb. But the angle is always taken as above.

If you would uſe the traverſing quadrants, then the obſerving, the plotting, and the proof in plotting,

ting, are all as eaſily, ſpeedily, and exactly done as by the firſt method; but the proof of the obſervation in the field, though equally true with the former, is neither ſo eaſily performed, nor ſo eaſily reduced to one ſingle rule. But the perſon who is reſolved to plot by the traverſing quadrants, had beſt take the obſervation both by the *Quadrants* and by the *Circumferentor*; and then prove the obſervation in the field by the *Circumferentor*, and the plotting by the traverſing quadrants.

Laſtly, If you would take the direction or bearing by the diviſions on the limb with a *Theodolite*, whoſe Box is fixed to the plate; then (having taken the angle as before ſhewn) turn the inſtrument about till the north end of the needle point at 360 degrees in the box, and ſcrew it faſt; direct the index to the next ſtation, and the end next you will give on the limb the direction in degrees and minutes, as in the former examples.

But with a *Theodolite*, whoſe box is fixed to the index, if you would take the direction by the diviſions on the limb; then (after the angle is taken, as before ſhewn) direct the fixed ſights to the next ſtation, ſcrew the inſtrument faſt, and turn the index about till the north end of the needle point at 360 degrees in the box; and then will the end of the index neareſt to the ſouth end of the needle cut on the limb the direction in degrees and minutes. But the *Protractor* to lay this bearing down, muſt be numbred contrary to the limb on the inſtrument.

The great advantage uſually propoſed by this laſt method, is, that the degrees on the limb are larger and more diſtinctly cut, and conſequently more nearly eſtimated than thoſe in the box. But conſider that you can no better bring the needle to point at any one degree, than you can eſtimate its poſition in any other degree; and that ſince we uſe the needle,

all

all the objections made in one method are incident to the other; and then you may eaſily conclude, that the advantage is only imaginary.

Beſides, here we are obliged to take two obſervations, either of which take up as much time as the obſervation uſed in the former method; which renders it not ſo fit for a practitioner.

Of the uſe of theſe *Theodolites*, I have one thing more to adverti ſe, *viz.* To meaſure and caſt up the content of one large ſingle Wood or Common, where there are ſome ſcores of angles to be taken; the ſafeſt way is to caſt, without plotting, by help of the needle. And in this caſe I would take the directions both with the *Circumferentor* and the *traverſing Quadrants*; and in the field prove the directions taken with the *Circumferentor* by the angles taken by the limb; and then, ſtill in the field, prove both lengths and directions, in calculating a traverſe, by help of a Traverſe Table; and laſtly, from this traverſe (at leiſure) deduce the true content.

But the Traverſe Tables that are now extant, are but ſpecimens of thoſe which are fit for uſe; inſtruments are not ſufficiently exact, and trigonometrical operations too laborious, and therefore this way of computation muſt be deferred, till ſome perſon who hath leiſure and patience to ſerve the world, in calculating ſuch a table, is reſolved to do it *.

Of any one of the four *Theodolites*, which have the numbers in the box contrary to thoſe *Theodolites* before deſcribed, one or more inconvenience will always ariſe, uſe which of the three forementioned methods you pleaſe.

It is true, the angle taken by the limb is performed as ſhewn in the preceding rules; but ſince

* Here the author promiſes if he can procure ſuch a table, as he hoped to do, to publiſh it with its uſes in Practical Surveying and Navigation: But he being long ſince dead, that deſign has dropped.

it is not ſafe to work by the limb only, if you uſe the *Circumferentor*, as ſhewn in the firſt rule, you muſt either ſubtract the direction from 360 degrees, and enter the remainder inſtead of the direction pointed at by the needle ; or elſe uſe two *Protractors*, which will be troubleſome, and alſo apt to cauſe miſtakes by uſing the one for the other.

If you uſe the *traverſing Quadrants* only, then indeed the uſe is in all reſpects the ſame with the preceding ones ; but theſe, as I have already ſhewn, are not ſo expeditious as, nor more exact than, the method firſt laid down.

If you will take the direction by the limb, and ſtill make one *Protractor* plot both obſervations, you muſt direct your inſtrument twice, whereas by the firſt method laid down, it might be done at once.

Laſtly, Of *Theodolites* thoſe are beſt which have teleſcopes with plain ſights on them, and ſo contrived that the ſurveyor may at any time adjuſt any ſmall accident, without coming to a workman ; and that both of them may be elevated or depreſſed at leaſt ten degrees ; one of theſe teleſcopes inſtead of the fixed ſights, the other inſtead of the moveable ones, and as long a needle as will play well, with other the like conveniences, ſufficiently known to a ſkilful inſtrument-maker.

III. *To obſerve with a Semicircle that hath a Box and Needle.*

A Semicircle is juſt half the *Theodolite*, and admits of juſt as many varieties; it is numbred on the limb to 180 degrees, and in an arch concentric to this is denominated by the numbers 190, 200, 210, *&c.* to 360 ſtanding under the former numbers 10, 20, 30, *&c.* Its uſe, in all reſpects (both to the plate and box) is the ſame with the *Theodolite*; ſave in this, that when the end of the index next the eye, falls off the plate, the degrees cut on the limb are to be taken from the further part of the index reckoned among the diviſions of the inner circle, and will be always more than 180 degrees.

There are other ways of numbering and dividing (and perhaps without a box and needle) uſed in theſe inſtruments; but they are not worth notice.

IV. *Of the Peractor.*

THE Peractor is the ſame with part of that *Theodolite*, whoſe box is fixed to the plate; and the directions given for the *Theodolite* in page 27, will ſerve for this.

V.

V. *Of the Plain Table.*

THE diviſions on the limb of the *Plain Table*, with its box and needle, being like thoſe of the *Theodolite*, or *modern Circumferentor*; if the 360 degrees on the limb be upwards, and the box and needle ſcrewed to the ſide of the table; it performs, in all reſpects, the uſe of the *Theodolite*, whoſe box is fixed to the plate. For lay the edge of the index on the diviſion numbered 360, and to that numbered 180; and turn the whole inſtrument about, till through the ſights you ſee the next ſtation (the 360 being towards you, as ſhewn with the *Theodolite*) and there ſcrew it faſt; then turn the index about upon the center, till you ſee the laſt ſtation, and ſo will the end of the index next you cut the degrees of the angle, and the ſouth end of the needle will give the direction or bearing.

But if the box be ſcrewed to the index, it in like manner becomes a *Theodolite*, with a box fixed to the index.

If the box and needle be ſcrewed to the ſtaff, it is a *Circumferentor*.

If the box be ſcrewed to the table, and that ſide of the frame be upwards, which is divided into four nineties, it is the *Perambulator*.

If that ſide of the frame is upwards, which hath only the 180 degrees of the ſemicircle numbered on it, then it is a ſemicircle, either with the box to the plate or not, according as the box is fixed to the table or to the index.

And what hath been already ſaid of theſe inſtruments may ſerve for directions, to uſe the plain table theſe ſeveral ways, and need not be again repeated here.

And

And hence it ſeems that the plain table might properly be called *Panorganon*, or the univerſal inſtrument, in reſpect of land ſurveying.

There are two ſmall holes towards the middle of the board, which ſerve as centres to the diviſions on the limb; the one for thoſe when the table is uſed as a ſemicircle, the other for the degrees numbered as in a *Theodolite:* In theſe holes the protracting pin is to be ſet while the ſloped edge of the index ſlides againſt it, and cuts the diviſions on the frame. Now if theſe holes were conical, and were the continuations of a conical hole in the index, ſo that the index could be fixed to them by a conical pin paſſing thro' its hole, and the central one, into which the pin ſcrewed, the fiducial or ſloped edge of the index being made to correſpond with the center of the pin; alſo if the diviſions on the frame be cut as accurately as on the limb of a *Theodolite*; and the wood would neither ſhrink nor ſwell any more than braſs; and a teleſcope mounted on the ſights; and the back ſide of the index brought alſo to a fiducial edge; then the plain table would be a very compleat inſtrument.

It remains to ſhew, how to take angles when we uſe the plain table covered with a ſheet of paper; but this hath been ſufficiently handled by Mr. *Leybourn*, and almoſt all the common writers on Surveying; therefore I ſhall content myſelf with laying down a method to correct an error committed before it is communicated to the following parts of the work. Though I do not any ways doubt but the reader may, by what follows, learn the uſe of this plain inſtrument.

Suppoſe you were to draw the plan of the field ALMNQR: (*Fig.* 20.) Draw on the table a line to repreſent AL in the field, and by the ſcale lay down on the plan the length AL was found to be in the field, when you meaſured it with a chain. Then

Then planting the table at L, lay the index on AL, and turn the whole inſtrument about till you ſee a mark ſet at A, then ſcrew it faſt, and turn the index about on L as a centre, till through the ſights you ſee M, draw LM, and by the ſcale, give it on the table the ſame length you found it to have in the field, by meaſuring with the chain.

Now in order to examine the length of LM, and alſo its poſition in reſpect of AL; plant the inſtrument at M, lay the index on LM, and by turning the inſtrument, direct the ſights to L, and there ſcrew it faſt; then direct the index turned about on M, towards A in the field, and if the edge does not cut the point A in the table, the line LM is falſe, either in poſition or length, and therefore muſt be examined and corrected before you proceed.

The line LM being truly laid down, plant the inſtrument at M, lay the index on LM, and direct the ſights to L, by turning round the table, and ſcrew the inſtrument faſt: Now turn the index about on M, till through the ſights you ſee the hair cut N, by the edge of the index draw a ſtrait line, and by your ſcale, from M lay the length NM equal to what you meaſured it in the field.

But to prove whether the line NM is truly laid down both in poſition and length; having planted the inſtrument at N, and directed the index laid on NM to M, and there ſcrewed the inſtrument faſt; from N direct the index to either of the marks L or A in the field; and if the index then does not accordingly cut L or A on the table, the line MN is falſe, and muſt be corrected before you proceed.

And in like manner through the whole ſurvey, you may proceed to lay down every line, and examine it before you leave it, (provided that you leave all your marks ſtanding at the ſtations,) by laying the index on the laſt line, and turning the inſtrument about till thro' the ſights you ſee the

hair cut the laſt mark; and then ſcrewing the inſtrument faſt; if you turn the index about on the point repreſenting the ſtation where the inſtrument ſtands, till you ſee any one of the marks paſſed by, except the laſt of all; and if the edge of the index does not cut on the table, the repreſentative of that point, the laſt line is not truly laid down.

But when from any ſtation, ſuppoſe N, you cannot ſee any other mark but M, ſet up ſome mark *a*, from whence you may ſee ſome of the preceding marks, ſuppoſe L, as well as M and N; and from this point *a* examine the truth of the poſition of the line MN.

Or thus; you may ſet up a mark *a*, any where in the field, from whence all, or ſeveral of the angles may be ſeen; then the inſtrument being at A, and the index on AL, ſcrew the inſtrument faſt; and turn the index on A, till you ſee *a*, and draw A*a*.

The inſtrument being at L, the index on LA, and the index directed to A; let the inſtrument be ſcrewed faſt; turn the index about on L, till thro' the ſights you ſee *a*, draw by the edge of the index L*a*; and ſo will the point *a* be determined.

Then the inſtrument being at M, the index on LM, the ſights directed to L, and the inſtrument ſcrewed faſt; turn the index about on M, till thro' the ſights you ſee the mark *a* in the field: Then if the edge of the index does not cut *a* in the table, the line LM is falſe either in poſition or length.

In like manner the table being at N, the index on NM, the ſights directed to M, and the inſtrument ſcrewed faſt; turn the index about on N, and direct the ſights to the mark *a*; and if the edge of the index doth not cut *a*, on the table, then MN is falſe either in poſition or length.

Laſtly, inſtead of a mark ſet up as *a*, you may uſe any remarkable tree, ſteeple, *&c.* not at too great

great a diſtance from you, whether it be in the land you are then ſurveying, or not.

And when the mark you have laſt uſed is at too great a diſtance from you, or lies almoſt in the ſame ſtrait line with that which you are about to lay down; then uſe ſome other mark in its ſtead.

VI. *Of working with the* CHAIN.

FIRST, provide a ſtaff juſt 6 foot 7 inches and two tenths long, which divide into 10 equal parts; and ſo will the whole be the length of 10 links, and each part the length of one, and 10 times the length of this ſtaff, the length of the whole chain.

With this ſtaff examine the length of the chain, and alſo of every 10 links; ſtretching it on level ground, to ſuch a degree as you deſign to ſtretch it, in the field work.

Before you meaſure with it, provide 10 arrows or ſmall ſticks, each about two foot long, and of ſuch thickneſs, that a man may conveniently graſp 10 of them in one hand; alſo two ſtrait ſtaves about 5 foot long each: The arrows may be made of *Ground Aſh*, a tough wood and not apt to break; let them be ſhod with ſharp-pointed iron ferrils at one end, and have pieces of red rag tied at the other end, whereby they will be very readily diſtinguiſhed and diſcovered when ſet down in long graſs or corn.

When you are about to meaſure with the chain, let him that leads it take the 10 arrows and one of the ſtaves; and he that follows it the other ſtaff.

Then the follower ſtanding at the ſtation, let him by motions with his hand to the right or to the left, as they have before ſettled it, direct the leader to place his 5 foot ſtaff at the chain's end in the ſame right line with the ſtations; and then let the leader

take up the ſtaff, and in its place ſticking down one of the arrows, go on.

Now the follower being come to the arrow, takes it up, ſets his ſtaff in the hole, and directs the leader to place his ſtaff as before.

And then let the leader, ſtanding at his ſtaff, look back towards the laſt ſtation, and he will ſee the ſtaves and the ſtation in one right line, if they have directed right. But if they are not in one right line, the leader muſt direct the follower to place his ſtaff at the chain's end, in the ſame right line with the ſtation, and the leader's ſtaff.

And ſo, let each direct the other, till the two ſtaves and the two ſtations are in one right line; and then muſt the leader put down an arrow in the place of his ſtaff, and go on: And the follower take up his ſtaff and the arrow where he laſt ſtood, and go after him.

And let them thus proceed till they have meaſured to the ſtation, or till the leader is nearer the ſtation than one chain's length; and then will the number of the whole chains meaſured, be expreſſed by the number of the arrows pricked down by the leader, and taken up by the follower, which ſuppoſe 8.

Now let the leader go on to the ſtation, and there hold the end of the chain, and let the follower ſtretch the chain as uſual, and then ſee how many links are contained between the laſt arrow and the ſtation; which may be readily counted by help of different bits of braſs, or curtain rings, or other marks fixed at the end of every tenth link, which links ſuppoſe to be 47.

Then enter in your field-book the chains and links without any diſtinction between them, and they will be 847; which imply either 847 links, or 8 chains 47 links.

But here we are to obſerve that the links muſt always poſſeſs two places; as 8 chains and 4 links muſt

muſt be written 804; that is 8 chains and 4 links, 804 links; and 8 chains without any links, muſt be written 800, implying 8 chains, or 800 links.

It is neceſſary that the ſurveyor ſhould enquire of his aſſiſtants at the end of every meaſured length, how many arrows each hath; and if the ſum of the arrows are not ten, it is evident they have dropt or left behind, thoſe that are wanting; and conſequently the laſt length meaſured is doubtful, and muſt be re-meaſured before you proceed.

When you are come to the ſtation, if it be convenient to continue the length, let the follower ſtand at the laſt arrow, and let the leader go on with the chain, and ſo place his ſtaff, that it and the two ſtations are in one right line; then in the place of the ſtaff put down an arrow, and go on; always directing himſelf to place his ſtaff, and conſequently his arrow, by the two ſtations.

When you have continued your length, till you have nearly loſt ſight of the fartheſt ſtation, ſet up another ſtation-ſtaff in the place of the laſt arrow, and continue the length by the two neareſt ſtations.

But withal take this caution, that it is not ſafe to continue lengths very long, when the ſtations are near one another.

When your length is very great, having meaſured ten chains, let the leader go on and ſet his ſtaff down at the eleventh; now let the follower put his ſtaff in the place of the leader's, and give the leader nine arrows, and then go on. But obſerve to enter in the field-book theſe ten chains, and never truſt to your memory. And if the length conſiſts of ten chains more, work as before, and enter 20 chains, and ſo on.

For a ſhift, the ſurveyor may perform many works with the chain; but this at beſt is both laborious and tedious, the only inſtruments for ſurveying all manner of lands both great and ſmall in all caſes,

being the *Theodolites* before mentioned; yet leſt there ſhould ſometimes be an abſolute neceſſity for taking the poſition of a line by the chain when other inſtruments are wanting, we have here added the method of taking an angle therewith.

In order to do this, provide three round ſticks, very ſtrait, and about four or five foot long. And if you were to take any angle as DBC (*Fig.* 21.) firſt place one ſtick upright in B, and there hold one end of the chain, and let your aſſiſtant carry the other end and another ſtick towards C, and direct him to move ſideways, till the ſtick held upright at E, be exactly in the right line BC, at the chain's end, where let him leave it.

Then let him take the end of the chain and move towards D, and, as before, direct him to plant the third ſtick at the chain's end upright in the line BD at F.

Then meaſure the diſtance EF in links and decimal parts of a link, if leſs than one chain, and enter them in the field-book: So if the diſtance EF were 94 links and 7 tenths of a link, they might be enter'd thus, $0^{s}\ 947^{Parts.}$ denoting 0 Sextants, 947 Parts; the ſextant ſtanding for the chord of ſixty degrees.

In this work great care ought to be taken, that the ſticks be as ſtrait as a workman can ſhoot them with a long plane; and that they are planted either exactly perpendicular, or at leaſt ſo that the ſticks planted at B and E, and the mark C may be exactly in the ſame plane, and alſo the ſticks B and F, and the mark D in another plane.

But becauſe it is very difficult to erect a ſtick exactly perpendicular, it will be eaſier to perform the latter thus; plant the ſtick as nearly perpendicular as you can; then move yourſelf backwards towards G, the farther the better, till your eye, the ſtick at B, and the mark at C, are all in one ſtrait line, there ſtand and direct your aſſiſtant to plant his ſtick,

ſo

ſo that the ſtick at B exactly cover it from the top to the bottom.

But if it ſo happen, that you cannot move backwards at all towards G; then having planted the ſtick at B, as upright as you can, let your ſecond aſſiſtant move forwards towards C, and let him there direct your firſt aſſiſtant to plant the ſtick at E, ſo that it exactly cover the ſtick at B, while you direct him to place it in a right line with the ſtick B and the mark at C; and the like caution muſt be uſed in planting the ſtick F. Nevertheleſs it will often happen ſo that the mark at D may be a little ſhifted, and in this caſe, time and trouble may be a little leſſened; for having planted the ſtick at F nearly in a true poſition, move forwards towards D, and direct your aſſiſtant to incline the ſtick at F, ſo that it exactly cover the ſtick at B, then returning to B, direct your aſſiſtant at D to place the mark in a right line with the ſticks B and F.

But, ſecondly, if the angle DBC is ſo great that the line EF be longer than the chain (as in *Fig.* 22.) lay out a ſextant; thus while the chain was laid from B to E, ſet down an arrow at H 50 links; then let your aſſiſtants hold the chain's ends at H and B, while you with the middle in your hand, move towards I and lay both halves ſtrait; ſet down an arrow at I, which conſtitutes the equilateral triangle HBI; and thereby gives the angle HBI a ſextant. Now the chain's end ſtill held at B, ſtretch it through the point I to K, where alſo ſet down an arrow; then meaſure KF in links and decimal parts of links, which ſuppoſe to be 76 links and 4 tenths; and then ſhall be entered in the field-book 1^{s} 764, implying one ſextant and 764 parts.

In like manner, if the angle were more than two ſextants (as in *Fig.* 23); then having laid off the ſextant HBI, let your aſſiſtants hold the ends of the chain at B and I, while you with the middle of the

chain in your hand ſet down an arrow at L, conſtituting the ſextant IBL; and then as before, the chain being ſtill held at B, lay it through L, and at the other end K, ſet down an arrow; then meaſure FK, which ſuppoſe to be 43 links and 5 tenths, and enter in the field-book 2^s 435, that is, 2 ſextants and 435 parts.

If you would continue a ſtrait line, ſignify it by entering in the book 3^s 000; that is, 3 ſextants.

If an angle be external, and ſo contain more than three ſextants (as in *Fig.* 24); let one aſſiſtant hold one end of the chain at B, and let the other aſſiſtant ſtand with the other end of the chain at E, and there hold a ſtick, ſo that E, B and C, are in the ſame plane as before ſhewn; and let him alſo plant a ſtick at F, ſo that the ſticks B and F, and the mark D be alſo in the ſame plane. Then meaſure the angle EBF as before, and to it add three ſextants, and ſo will the ſum be the meaſure of the external angle CBD. So if the angle GBD be 0^s 947, then will the external angle CBD be 3^s 947. But if the angle GBD be 1^s 764, then the external angle CBD will 4^s 764. And if the angle GBD be 2^s 435, then the external angle CBD will be 5^s 435.

Now to plot any of theſe angles thus taken (ſuppoſe that in *Fig.* 21); chuſe ſome line divided into 1000 equal parts, and with this line as a radius from the center B deſcribe an arch ER, and lay thereon from E to F 947 equal parts and draw BD.

And if you would plot the angle taken in *Fig.* 22; from B with the length of the divided line, deſcribe an arch EF, and lay thereon the length of the divided line from E to K, and afterwards 764 parts from K to F, draw the line BFD, and you will conſtruct the angle required.

Again,

Again, if you would plot the angle of *Fig.* 23; then as before, with the length of the divided line, from B deſcribe the arch EF, and thereon lay EP, PK, each equal to the radius; and afterwards lay 435 equal parts from K to F, draw BF; and you have the angle required.

And if you would protract an angle greater than three ſextants (as the external angle CBD in *Fig.* 24); firſt continue the line CB, then from the angle ſubtract three ſextants and make the angle GBD equal to the remainder.

Angles about gardens or buildings may be taken with rods of 5 and 10 foot, and laid down in all reſpects as with the chain, but are no ways fitting for large plans.

If the ſurveyor has only a chain, and having drawn his plan, would draw thereon a meridian line; he may do it thus; exactly at twelve a clock, mark the ſhadow of ſome upright object, as the corner of a houſe, or ſome ſtrait tree, or your ſtaff ſet upright; then plot this line on your plan, and it is a meridian line.

Or thus; in a night when the *Pole ſtar* is to be ſeen, place yourſelf ſo, that your eye, the *Pole-ſtar*, and ſome upright object, as the corner of a houſe, or the ſide of a ſtrait tree, be in one ſtrait line; then plot the line from your feet to the upright object, and it will be a meridian line.

Indeed the *Pole-ſtar* moves round the real pole; but at ſo ſmall a diſtance from it, that in this caſe the variation may be rejected.

How-

However, you may obſerve that the *Pole-ſtar* is full north about the 20th day of

- *March* and *September* at 12,
- *April* and *October* at 2,
- *May* and *November* at 4,
- *June* and *December* at 6,
- *July* and *January* at 8,
- *Auguſt* and *February* at 10

a clock either morning or evening; always increaſing nearly 2 hours for every month.

Therefore if the obſervation is made about theſe times, the variation will be very inconſiderable.

Alſo obſerve, that 5, 6, or 7 hours before or after theſe times, if the pointers are to the eaſtward of the pole, then the variation of the ſtar is about 3 degrees and a half weſtward; and is then the greateſt.

But if to the weſtward of the pole, the variation is about $3\frac{1}{2}$ eaſtward, and then at the greateſt.

Note, The pointers are the two hinder wheels of the conſtellation called *Charles*'s *Wain*, which are obſerved to be always in a direct line with the *Pole-ſtar*.

SECT.

SECT. IV.

To caſt up the CONTENTS *of* LAND, *with the Method of reducing* Irregular Curves *to* Strait Lines.

THE contents of any field may be readily caſt up thus: Take each baſe and perpendicular of every triangle, and each diagonal of every *Trapezium*, in links, eſteeming every chain 100; in every *Trapezium* multiply the ſum of the perpendiculars by the diagonal; and in every ſingle triangle, the baſe by the perpendicular; then add the ſeveral products together: Put a point between the fourth and fifth places, and another between the fifth and ſixth, reckoning from the right hand; then halve the figures to the left hand of the points, and ſo will this half be acres; if an unit remain, that unit is an half acre or two roods; and if the figure between the points be five or more, take five from it and account it another rood. Then, multiply the remaining figure 0 between the points, by 8, and to the product add the tens to be carried from the fourth figure, and you have the perches. If any perſon is ſo curious, as to eſteem the decimal parts of the perches, they will be the product made by multiplying the figures to the right hand of the point by 8. So in figure 25 the operation will be thus.

313=AC ; 214=KL ; FG=418
612=DE ; 396=HI ; AH=900

925 610 376200
725 = BF 500=FM

4625 305000
1850
6475 670625
670625 305000
376200

13|5|1825
A. R. P.

Anſwer, 6 : 3 : 1

Here half of 13 gives 6 the acres, and one remaining is 2 roods ; then the 5 between the points gives another rood ; and ſo the whole is 6 acres and three roods ; and becauſe there is but one ten to be carried from the fourth place, and that after the 5 is taken out of the fifth, there remains nothing, there is but one perch.

In like manner, if the whole ſum of all the

			A. R. P.
Products be	17|4|5364	the content is	8 . 2 . 36
	11|9|2765		5 . 3 . 34
	10|5|4321		5 . 1 . 03
	8|4|3764		4 . 0 . 35

So if the ſum of the products be 41|7|6354, the content is 20 . 3 . 21|0832. But this method muſt be only uſed when the figure is reduced to triangles and trapeziums.

It may not be improper, to add in this place, the manner of caſting up ſuch fields as conſiſt of many

ſmall

ſmall breaks in the hedges; without reducing them to a multitude of triangles; thus.

Let *Fig.* 26. be ſuch a field; produce NM, one of the longeſt ſides; then lay the edge of a ſtrait ruler from M, one of the angles at the end of NM, to G the next angle but one; holding the ruler thus faſt, take with a pair of compaſſes the diſtance from L to the edge of the ruler, and with this diſtance let one point of the compaſſes move gently cloſe to the ruler, while the other point traces out a line parallel to it, and croſſes NM in Q. Now draw GQ, and it will reduce that ſide of the figure, which was bounded by the two lines ML LG, to another bounded by GQ, one ſingle line only.

In like manner QG being produced, and a ruler laid from G to E, carry the diſtance of F from the ruler parallel to it, till you croſs QG in K. Then lay a ruler from K to the next point D, and carry the diſtance of E from the ruler parallel to it, till you croſs QG in H. Now lay a ruler from H to the next point C, and carry the diſtance of D, the laſt point from it, parallel, till you croſs QG in I. Laſtly, draw IC, and the ſide GC which conſiſted of the four lines GF, FE, ED, DC, will be reduced to the ſide IC, conſiſting of one line only. And in like manner we might proceed if the lines were never ſo many.

And thus laying a ruler from C to P, draw PO; and in like manner AQ. So will the ten-ſided figure be reduced to a four-ſided one, and ſo may be caſt up by one multiplication only. The practice of this will be rendered vaſtly eaſy by help of a parallel ruler.

Provide a plate of thin braſs in form of an arch of a circle; near whoſe ends let there be drilled ſmall holes, through which ſtring it with a very fine hair or wire. Being thus provided; when a hedge at GC bends in and out in ſeveral places, and thoſe

bends contain very ſmall ſpaces, lay the hair over it lengthwiſe, ſo that the quantities thereby cut off from the figure may be equal to thoſe added to it; and with your protracting pin, near the ends of the hair, make two marks, through which draw a ſtrait line; and ſo will this irregular ſide be reduced to a regular one. And here we may obſerve that in very ſmall bends, we judge better by the eye than we can by the compaſſes of the equality of the parts taken in and left out.

But, if hedges conſiſt of large curvatures, chuſe out ſuch points, and ſo many of them, that right lines drawn from point to point, may vary the quantity by ſuch parts only as may be rejected. And herein your hair will be a ready aſſiſtance.

SECT. V.

Of the Laying out, or Dividing of LAND.

WHEN any number of acres, roods and perches are to be laid out, or meaſured off from another field, it is convenient to reduce them to ſquare links, which may be done thus:

If the roods are $\left\{\begin{matrix}1\\2\\3\end{matrix}\right\}$ add $\left\{\begin{matrix}40\\80\\120\end{matrix}\right\}$ to the perches, and to the ſum annex 4 cyphers. Divide this laſt by 16, or by 4 and 4, and write the quotient figures, if they conſiſt of 5 places, after the acres.

But when the number of quotient figures are but $\left\{\begin{matrix}4\\3\end{matrix}\right\}$ write $\left\{\begin{matrix}\text{one cypher}\\\text{two cyphers}\end{matrix}\right\}$ after the acres, and then the quotient figures; and ſo will you have the ſquare links required.

Ex.

A. R. P.

Ex. I. *Reduce* 7 2 24 *to ſquare links.*

to 24 *perches,*

Add 80, *becauſe* 2 *roods*

16)1040000(65000

80000

..

Anſwer 765000.

A. R. P.

Ex. II. *Reduce* 7 0 11 *to ſquare links.*

to 11 *perches*

Add 0 *becauſe* 0 *roods,*

4)110000

4) 27500

Quotient 6875 *has four places.*

Anſwer 706875.

A. R. P.

Ex. III. *Reduce* 7 0 01 *to ſquare links.*

to 01 *perches,*

Add 0 *becauſe* 0 *roods,*

16)10000(625 *three places*

40

80

Anſwer 700625.

A. R. P.

Ex. IV. *Reduce* 13 3 37 *to ſquare links.*

to 37 *perches,*

Add 120 *becauſe* 3 *roods,*

4)1570000

4)392500

Quotient 98125 *has* 5 *places.*

Anſwer 1398125 *ſquare links.*

In

In the laying out of lands, there are three caſes, or Problems, which ariſe in practice.

For, either the partition line is required to be parallel to ſome other line aſſigned, or is to paſs thro' ſome point aſſigned in the fence, or to paſs through ſome point aſſigned within the land.

In the ſolution of each of theſe caſes, I chuſe an arithmetical approximation rather than a geometrical conſtruction; for reaſons ſufficiently known to thoſe who have practiſed.

Note, When a quantity of land is to be laid out, or taken off from a field; it is neceſſary to have an exact plan of the place, or field; and this is ſuppoſed in the following problems.

PROB.

PROB. I.

From the Field HGEKF, Fig. 27.

Let it be required to cut off towards AB, 8 *Acres*, 3 *Roods*, 18 *Perches*, *by a line drawn parallel to* AB.

FIRST draw parallel to AB a line CD by gueſs, near the place where tis imagined the partition line ſhould be; and then caſt up the content of the figure CDHG, which ſuppoſe to be 772575 ſquare links, which is leſs than $8^{A.}\ 3^{R.}\ 18^{P.}$, or 886250 ſquare links, by 113675 ſquare links; which ſhews, that the partition line ſhould be more towards K.

Now divide the exceſs 113675, by 965, the length of CD in links, and at the diſtance of 118 links, the quotient, draw EF parallel to CD, and it will be ſufficiently near the partition line required.

But if by curioſity you are led to correct the variation; you may conceive CD to be a line given in poſition, and 113675 ſquare links, to be the quantity to be cut off, and EF the line drawn by gueſs.

But if the line CD had cut off the quantity CDHG greater than that required; then the partition line had been more towards GH, whoſe diſtance from CD would be found as before, by dividing the difference by the length of CD.

PROB. II.

From the Field LMPQRSTW, Fig. 28.

To cut off $5^{A.}\ 0^{R.}\ 35^{P.}$ *towards the corner* L, *by a line drawn from the point* V.

REduce the given quantity $5^{A.}\ 0^{R.}\ 35^{P.}$ to ſquare links, and they will be 521875.

Then draw LV, forming the triangle VLW, which being caſt up, amounts to 30800 ſquare links, which is too little.

To the next angle draw VM, forming the triangle VLM, which being caſt up will be found to amount to 297632 ſquare links, which added to the triangle VLW, you have 328432 ſquare links, the content of the *Trapezium* VWLM, which is ſtill too little.

To the next angle draw VP forming another triangle, whoſe content 403850 ſquare links added to 328432, the content of the preceding figure, gives 732282 ſquare links; which is more than the required quantity, by 210407 ſquare links; therefore the partition line muſt paſs between P and M.

Divide the exceſs by 497, half the length of VO the perpendicular in links, and lay 423 the quotient from P to N, and ſo ſhall VN be the true line of partition.

PROB.

PROB. III.

In the Field BCFGH, Fig. 29.

To lay out $7^{A.}\ 3^{R.}\ 13^{P.}$ *towards the corner* B, *by drawing one or two lines thro' a point* A *within the field.*

TO perform this with one line: Conſider through which two ſides of the field the partition line will paſs. Reduce the figure to a *Trapezium*, ſtill retaining thoſe ſides, as ſhewn in page 45. Which divide by a line through the aſſigned point A.

But, becauſe this method is tedious, and depends on the concourſe of many lines; and though we ſhould uſe numbers, we ſhould little mend the matter, and indeed is often impoſſible to be performed by one ſingle line; it may not be amiſs to ſhew how to do it by two lines.

From A to any two angles H and B, draw the lines AH, AB, forming the triangle AHB, this being caſt up, amounts to 338000 ſquare links, which is leſs than the quantity required.

To the next angle C, draw AC forming the triangle ABC, which being caſt up, amounts to 322500 ſquare links; which added to the triangle AHB, gives 660500 ſquare links; which are ſtill leſs than the quantity required.

To the next angle F draw AF, forming the triangle ACF, whoſe content 280800 ſquare links, added to the preceding triangles AHB, ABC, gives 941300; which exceeds the quantity required by 158175 ſquare links; now divide this exceſs 158175 by 292, half the length of the perpendicular EA, lay the quotient 541 from F to D, and draw AD; and ſo will the lines AH, AD, be the partition lines required; and the figure AHBCD will contain the given quantity which was to be laid out.

SECT. VI.

The uſe of the Theodolite *exemplified in Surveying ſeveral parcels of land lying together, with the form of a* Field-Book.

AFTER a general deſcription of inſtruments and their uſes, ſome practical examples are neceſſary to illuſtrate and explain the particular varieties which often occur.

The following example is delivered in the ſame method which at this time is commonly practiſed.

The inſtrument uſed in this ſurvey is a *Theodolite* numbered on the limb from the left to the right, and in the box (which is fixed to the index) the ſame way; the eye being ſuppoſed in the center.

The *Chain*, the *Off-ſet-Staff*, the *Arrows*, &c. are as deſcribed in the third Section.

In one end of the *Off-ſet-Staff*, it will be convenient to ſcrew in a piece of iron, having at the end a kind of fork, whoſe legs ſhall be juſt long enough to embrace the hand-ring of the chain, which being put in the fork, the end of the chain may be thruſt through a hedge by the means of the *Off-ſet-Staff*, to the leader of the chain on the other ſide of the hedge.

The field-book may be divided into three columns. The middle one contains the ſeveral lengths taken by

by the chain: And the outside columns contain the several off-sets, and the description of the most remarkable objects, which are to be met with in the survey.

By the mark ⊙ is denoted a station; by ∠ an inside angle; and by ⅂ an outside angle: by (*B*) is denoted a bearing; by *Int.* the cutting a hedge by the chain; by *ag.* some remarkable object on the farther side of the hedge. These symbols are used instead of words, because they constantly fall in the way; but other objects which are more rarely met with, I express by words.

Being thus provided, in the first page of the field-book, near the top, enter the title of your survey: Then having fixed the instrument in some convenient place, as A to begin at, I enter in the middle column the mark ⊙ 1. denoting the first station.

Here observe, that I always chuse to work in a lane, as often as opportunity presents.

The instrument being planted at A, I send a station staff forwards in the lane as far as I can see distinctly, the farther the better, suppose to (B 3.) and when I work in the land, I send a station-staff to the next eminent bend in the hedge, or even to the farther end of it, if the line from the instrument to the staff be not at too great a distance from the hedge, so as to cause off-sets greater than a chain, or a chain and a half, or thereabouts. For off-sets taken too great, produce some uncertainties.

Then I observe the bearing of the line AB, thus; the flower-de-luce in the box being towards me, I direct the sights to B 3, and then find the needle cut 327°, which I enter in the middle column under ⊙ 1, thus, *B* 327°.

Note, By the instrument used in this example, the bearing is accounted from the north, westward quite round to 360°.

The observation being made of the line's position, which I am about to measure, the next thing is to lay

the chain from this ſtation A in a right line towards the next ſtation B 3 ; which being done, I let it lie, till I have entered the occurrences in this chain's length ; *viz.* I meaſure the diſtances of the chain from the brow of each ditch, which I enter in the outſide columns, that on the right hand of the chain in the right hand column, that on the left in the left hand column ; and alſo the names of the perſons who own theſe lands abutting ; or if theſe lands are ſome of thoſe which I am about to ſurvey, I enter the names of them ; and in all caſes expreſs to which land the hedge belongs.

Theſe precepts will not be repeated, tho' I ſhall ever make uſe of them ; but if any other are uſed, they will be laid down the firſt time they occur in this example, but not afterwards.

Now I enter 0 in the middle column, and 20 in the right hand one, and 20 in the left ; denoting, that at no diſtance, or at the inſtrument, the ditch on the right hand is 20 links from the chain, and that on the left alſo 20. In the right hand column I write *William Wary*'s *land*, *hedge to Wary* ; and in the left, *Lord Title*'s *land*, *hedge to Lord* ; becauſe the land and hedge on the right is *Wary*'s, and that on the left *my Lord's*.

Being now come to *a*, I am right againſt the ſouth hedge of *Hazle Spring*, and alſo of *Woodfield*, and there find the diſtance from the ditch on the right hand to be 25, and on the left to be 20, and that afterwards the hedge on the right hand belongs to *Hazle Spring*, and on the left to *Woodfield*. Therefore I enter in the middle column 65, and in the right hand column 25, *ag.* hedge to *Hazle Spring*, hedge to *Spring* ; and in the left 20, *ag.* hedge on *Woodfield*, hedge to Field.

Here it may be obſerved, that theſe off-ſets, or diſtances of the chain from the hedge, are meaſured (with my ten-link ſtaff, which I therefore call my

Off-ſet-

Off-ſet-Staff) perpendicular to the chain, and ſo far till I come to that brow of the ditch, which is fartheſt from the ſtem of the hedge: And that here by the brow of the ditch, I mean the determined diſtance of five links from the ſtem of the hedge. And in order to lay this ſtaff perpendicular to the chain, it would be convenient to have two pieces at one end of it at right angles, like the ſquares uſed on a drawing-board; and theſe pieces, for convenience of carriage, may be made to fall into the ſtaff, by ſprings like a claſp-knife.

Having entered theſe obſervations in the firſt length of the chain, I obſerve what place of the ground is exactly under the center of the inſtrument, by dropping a muſquet-ball, or plumbing it with a ſtring and weight; then I remove the inſtrument, and in that place fix, as upright as can be, a ſtation-ſtaff, and then proceed with the chain.

And becauſe in the ſecond and third lengths of the chain I meet with no ſenſible turns in the hedge, nor other material occurrences, I go on to lay it a fourth time, and there againſt 45 links I find a bend in each hedge; where on the right hand the brow of the ditch is 50 links diſtant from the chain, and on the left 40; therefore in the middle column I enter 345 (denoting 3 chains 45 links) and in the right hand column 50, and in the left 40.

And here it may be obſerved, that I take off-ſets only at each end of ſuch parts of a hedge, as run very nearly ſtrait, omitting the intermediate parts; ſince when the extremes of a right line are given, that right line itſelf is alſo given: So here, though the diſtance of the hedges from the chain between *a* and *b* continually vary, yet I only take the off-ſets at *a* and *b*, ſince theſe are ſufficient. But when the hedge runs on with a continued but irregular curvature, I take off-ſets at every chain or half chain's length, or perhaps oftner, as the thing requires. But

when the curvature is regular, I take its extremities by off-ſets, and expreſs its nature by a ſketch, in the outſide columns.

In going on from *b* towards B, when I am come to *c*, the chain touches the brow of the leſt-hand ditch, againſt 20 ; then I aſk the hindmoſt man, or the follower of the chain, how many arrows he hath? he anſwers 5 ; then I enter in the middle column 520 (denoting 5 chains 20 links) and in the left hand column 00, denoting that the brow of the ditch is at no diſtance from the chain. The chain ſtill lying, againſt 40 links, I find a bend in the right hand hedge, where the ditch is diſtant from the chain 50 links.

Now it may be obſerved, that I frequently aſk the follower of the chain, and alſo the leader, how many arrows they have? eſpecially when I am about the off-ſet or other occurrence, partly to know the number of the chains, and partly to prevent the loſs of an arrow ; for this always raiſes a doubt of the length, and muſt be removed before we proceed ; and leſt when a ſtick is dropped, another may be picked up in its room, I always give my arrows ſome marks of diſtinction.

If the ſum of the arrows in both my aſſiſtants hands are leſs than ten, then the laſt length muſt either be re-meaſured, ſince it is doubtful, or elſe the ſurveyor muſt ſtep it, and thereby diſcover which of them dropt it : And this, with a little practice, he will eaſily do by counting his ſteps, and uſing himſelf to ſtride about the ſame diſtance each ſtep ; and by looſing a button of his coat when he hath gone as many ſteps as (by experience he knows) carry him the length of a chain. And hence he may know exactly the number of the chains, though he cannot perhaps find exactly the odd meaſure. But the number of chains is ſufficient, becauſe the error by dropping arrows always falls in whole chains.

In

In like manner, at the length of juſt 800, becauſe the chain touches the right hand ditch, and is diſtant from the bend in the left hand 40 links, I enter in the middle column 800, in the right hand column 00, and in the left 40.

Then I continue on to my ſtation-ſtaff at B^3, which I find to be at the length of 825, where, becauſe there is no bend in the hedge, nor other material occurrence, I enter 825 in the middle column, and under it I draw a line, denoting that this length, and all the occurrences therein, are obſerved and entered in the field-book.

Since I have endeavoured to be plain and eaſy in this firſt length; ſo ſhall I, in the following part of this example, be as conciſe as may be, unleſs where ſomething ariſes not before ſpoken of; referring the reader rather to the field-book and explanations, than tiring him with repetitions.

Being come to B^3, I there ſo plant the inſtrument by help of the plummet, that its center is directly over the hole, which the ſtation-ſtaff ſtood in; and I ſend my ſtation-ſtaff forwards, as far as I can conveniently ſee it as to C.

Now with the beginning of the degrees towards me, I direct the fixed ſights back to the ſtaff at A, and ſcrew the inſtrument faſt: And then with the Flower-de-luce towards me, I direct the index to the ſtaff at C, and there find, that the end of the index next me, cuts 202° 45′, and the ſouth end of the needle points at 304° 15′. Therefore I enter in the middle column of my field-book, ⊙ 2, and under it ∠ 202° 45′, and next under this *B* 304° 15′; denoting, that at the ſecond ſtation, the angle made, is 202° 45′, and the bearing of the ſecond length is 304° 15′.

But before I proceed, I examine theſe numbers thus: To the bearing of the laſt ſtation 327°, I add the conſtant number 180, and from the ſum 507°, ſubtract

ſubtract the preſent bearing 304° 15′; and find the remainder 202° 45′, exactly equal to the angle.

Or elſe, to the angle 202° 45′, I add the preſent bearing 304° 15′; and from the ſum 507° ſubtract the conſtant number 180, ſo ſhall the remainder 327° be the bearing of the laſt length exactly, as taken at the laſt ſtation.

And this operation I place in the outſide column againſt the ſame angle and bearing, to ſignify, that the angle and bearing have been compared, and do agree.

But if theſe numbers thus compared, do not agree, the preſent angle and bearing muſt be examined and corrected; and if, after ſuch examination, they do not agree, there is an error in the laſt bearing, which may be taken again; thus,

The inſtrument ſtanding in the ſame place, I direct the index, the Flower-de-luce being from me, to the laſt ſtation-ſtaff at A; and then will the ſouth end of the needle point at the ſame degrees which it did when the inſtrument ſtood at A, and the index was directed to B³.

Having thus taken, entered and examined the angle and bearing, I proceed with my chain, and find the lengths and occurrences to be as you ſee them in the field-book.

Then fixing the inſtrument at C, as before ſhewn, obſerving always to ſet the plate horizontal by the help of a ſpirit-level, or otherwiſe; I ſend a ſtation-ſtaff forward to D, and obſerve, enter, and prove the bearing and angle at C; and then ſtretching the chain towards D, I find at the length of 250, a gate on my right hand, and at 260, at the diſtance of 10 links, the corner of *Hazle-Spring*. Therefore in the middle column I enter 250, and right againſt it, in the right hand column, I write *Gate*; again, in the middle column, I enter 260, and right againſt it, in

in the right hand column, 10 *Corner*. And then proceed to the ſtation-ſtaff at D.

Having finiſhed the length CD, and fixed the inſtrument at the fourth ſtation D, I do not go up the lane towards E, but turn off towards L; in order to cloſe in *Hazle Spring* and *Spring Cloſe*; always obſerving this rule, *viz.* Never to make a tour greater than neceſſity requires, but always to cloſe as often and ſoon as poſſible.

Therefore having ſent a ſtaff to L; I obſerve, enter and prove the angle and bearing at D.

Here it may be obſerved, that when I came to K in the firſt length, the hedge on the left hand belonged to *Woodfield*, and not to the lane; and therefore I entered in the left hand column, *Hedge to Field*; and ſince this note, the hedge on the left hand hath continued to belong to the ſame *Woodfield*; therefore I have not repeated that occurrence. But in going from D to L, at the length of 15 links, I am againſt the corner of *Long Mead*, and 10 links diſtant from it, and then the hedge belongs to *Long Mead*. Therefore after ⊙ 4. ∠ 259° 20′, *B* 261° 10′, I enter in the middle column 15, and on the left hand 10 *Corner*, then on *Long Mead*, then *Hedge to Long Mead*.

But becauſe on the right hand we have ſtill *Hazle Spring*, and the hedge is ſtill to the Spring, and becauſe theſe have been always on the right hand ſince I firſt entered them; I go on without any farther remark, till I meet with a different occurrence.

Being come to L, I obſerve, enter and prove the bearing and angle, and then proceed to M. At M I obſerve and proceed in like manner to N. But at N, the ſeventh ſtation, inſtead of going on in the line, I proceed to cloſe in *Hazle Spring*, and therefore ſend a ſtation-ſtaff to O in *Spring Cloſe*.

Therefore at the ſeventh ſtation N in the lane, having obſerved, entered and proved the Angle MNO,

MNO, and the bearing of the line NO, and directed the chain from N towards O; I find the chain cuts the brow of the ditch at 10 links diſtant from N; therefore in the middle column I enter 10 *Int.* denoting the chain's interſecting the hedge, and then I write *In Spring Cloſe*, denoting that the land we are in is called *Spring Cloſe*; and in the right hand column, but the next line, I write *Hazle Spring*, and under this, *Hedge to Spring*, denoting that the land on our right hand is *Hazle Spring*, and that the hedge belongs to the ſame. Then I proceed to obſerve, meaſure and enter thoſe occurrences as they are found in the field-book, till I come to O.

At O, I obſerve, enter and prove, and proceed as uſual towards Q; noting that at the length 720 the chain did cut the hedge in the very corner of the fence; and therefore enter in the middle column 720 *Int.* and in the right hand column 00 *Corner*, and then in the middle column I write, *In William Wary's Land*; and ſo proceed to Q.

Being come to Q, the ninth ſtation, I ſend a ſtation-ſtaff towards A; and then obſerve, enter and prove my angle and bearing; and ſo proceed with the chain, entering all occurrences, as in the field-book; till coming to the length 830, I find myſelf right againſt the corner of *Hazle Spring*, and 43 diſtant from it; which being entered as you ſee in the field-book, I write in the middle column * *Cloſe Hazle-Spring*, denoting that the extremity of this off-ſet coincides with the firſt off-ſet taken to *Hazle Spring*.

Having thus compleated *Hazle Spring*, I return to N, my ſtation in the lane, according to that general rule I always obſerve, of working in a lane, and according to that rule of cloſing as often as poſſible.

Now, turning back the leaves of my field-book, I find the ſtation, immediately before my coming into

into *Spring Close*, was by number the seventh. Therefore, in my field-book, I enter ⊙ 7.

But here it may be observed, that whensoever I design to return to the same station, before I leave it, I cut a turf from the hole where the staff stood, or leave some other mark, whereby I may exactly find it again readily; and in the field-book to the mark ⊙, I prefix the letter *R*, or write the word Return: by which, and the other concomitant notes, I readily discover the number of the station.

But when the ⊙ to be returned to, falls in a way where many carriages, *&c.* pass; or when it may be thought proper, as a cheque on the foregoing work, to direct a line from some convenient ⊙ to a former ⊙, several days after you departed from that former ⊙; in such cases, it will be best to drive a plug, cut from a hedge-stake, and pare the ground away, or leave a few stones, about this plug; or make some mark in the hedge opposite to this plug, whereby it may be readily found again; observing to conceal these plugs or marks from the country-people, who in general, hating the practice of taking surveys of their grounds, will frequently remove the surveyor's marks, either to give him trouble, or divert themselves.

And for the convenience of the ready cutting and driving of these plugs, one of the assistants should have a small hatchet stuck in his girdle; besides, such an instrument is often wanted to cut away the small stuff in a hedge, in order to open a proper view to the station-staff.

Having now planted my instrument a second time at N, and sent a staff forward to R, I observe the angle MNR, made by the line NR, I am next about to measure, and the line MN, that which I measured immediately before I came to N the first time.

And

And this I always make a conſtant rule, *viz.* To obſerve the angle with that line which was meaſured immediately before I came to the ſtation, where I took the angle the firſt time. So here I obſerve the angle made with MN, and not with any other as ON, and therefore in proving the angle MNR, I uſe the bearing of MN taken at M.

Now having taken, entered and proved the angle MNR, and the bearing of NR, I go on with the chain towards R, entering the ſeveral occurrences as you find them in the field-book.

Being come to R, the tenth ſtation, tho' my deſign is to incloſe *Spring Cloſe*, yet becauſe the laſt length, continued ſtrait forwards, will take the ſouth hedge of *Long-Mead*; in the middle column I enter ⊙ 10, ∠ 180, *B.* 274. 45. and then direct the leader of my chain to lay it right forwards by help of the ſtations R and N; and accordingly I enter the occurrences of that length, as you ſee in the field-book.

This finiſhed, I return to R, and ſending a ſtation-ſtaff to S, I enter again ⊙ 10, and the angle and bearing at R, and ſo proceed to S.

And then from S to T, and ſo from T the 12th ſtation to P, incloſing *Spring Cloſe*.

Spring Cloſe being finiſhed, I return to my fourth ſtation at D; and ſend a ſtation-ſtaff forwards to E, and then under ⊙ 4, obſerve and enter the bearing of DE, and the angle CDE; and then by the bearing of CD, taken at the ſtation C, immediately before I came to D, prove the angle CDE, and proceed with the chain, entering all occurrences as uſual.

Being come to E, I ſend a ſtation-ſtaff to F, in order to cloſe in *Woodfield*. Now, after I have obſerved and entered the angle and bearing at the thirteenth ſtation E, when I come to prove them, I find by adding 180° to 353° 15, the bearing of the line

which brought me to this ſtation; and when from the ſum 533° 15′, I have ſubtracted 82°, the preſent bearing, I find the remainder to be 451° 15′, a number greater than the 360. Now as oft as this happens, I leſſen this number by 360 degrees, and ſo will the remainder be, as in this example, 91° 15′, the preſent angle exactly.

Then entering the occurrences, I proceed to F, and in like manner from F to G, from G to H, from H to I, and then from I, the ſeventeenth ſtation, to K, thereby incloſing *Woodfield*.

This done, I return to E, and there becauſe I can continue my length DE, right forwards conveniently, I enter ⊙ 13, ∠ 180° 00′, *B*. 353. 15. and then go on to V.

And then entering angles, bearings, and other occurrences, I proceed from V to W, and from W to X, the 20th ſtation.

Being come to X, and having entered 7 234° 20′, and *B* 307° 40′, then after I have added 180° 00′ to the laſt bearing 2° 00′, I find the ſum 182° 00′ is leſs than 307° 40′ the preſent bearing: In ſuch caſes I always add 360 to the ſum 182, and then from the reſult, taking the preſent bearing 307° 40′, the remainder will be, as in this example, 234° 20′, the preſent angle.

Then I proceed to Y, and from Y to Z.

Being come to Z, the 22d ſtation, in order to encloſe *Long Mead*, I go off to α, from α to β, from β to γ; where, becauſe the ſeveral bends of the river cannot ſo commodiouſly be taken without it, from γ I go off to δ; and then from γ to ε, from ε to ζ, from ζ to η, and from η the 28th ſtation, to θ; thereby incloſing *Long Mead*. And then return to Z. But obſerve that at ſtation 23 where the river falls in, the breadth ſhould be taken, and wrote in the field-book; and in coaſting the river, its breadth ſhould be taken in ſeveral places, and marked

marked in the field-book; alſo at ſtation 28 where the river ceaſes to be the fence, it muſt be noted, together with its breadth; the courſe of the river, or the way it runs muſt be likewiſe entered in the book.

Being come to Z, I find it convenient to continue my length ſtrait forwards; and therefore under ⊙ 22, I write ∠ 180, and ſo go on to $\varkappa$, from $\varkappa$ to λ, from λ to π; and then in order to incloſe *Butts Cloſe*, I go off from π, the 31ſt ſtation, to ρ, and ρ to σ.

Then returning to π, I go on to A^2 the 33d ſtation, and then, in order to cloſe the *Home Cloſe*, I go off to B^2, and ſo then to C^2, and D^2.

Returning then to A^2, I go on to E^2, from E^2 to F^2, from F^2 to G^2, and G^2 to H^2, the 39th ſtation.

Being come to H^2, in order to cloſe in *Mottle Mead*, I go off to I^2, from I^2 to K^2, from K^2 to L^2, the 42 poſition, and from L^2 to M^2, and ſo is *Mottle Mead* finiſhed.

Then in order to incloſe *Hazle Wood*, I go from L^2 to N^2, from N^2 to the angle at F, and ſo is *Hazle Wood* finiſhed.

Then I return to H^2 the 39th ſtation, and thence go to O^2, and from O^2 to P^2, the 45th ſtation.

And now, in order to cloſe in *Hazle Field*, I go from P^2 to Q^2, and from Q^2 to T^2.

Which being done, I go from P^2 to R^2, and from R^2 to S^2; and ſo the whole is finiſhed as you find it in the field-book; and as far as relates to the field work.

It remains to ſhew, how this work may be plotted without any regard to the memory; nay, though it were ſurvey'd by one perſon how it may be plotted by another who never ſaw the land; provided that the perſon who ſurvey'd it, hath ſtrictly obſerved the rules here laid down. And I do affirm, that any

any method of keeping a field-book, which lays a burthen on the memory, or by which, a perſon remote from the land, cannot plot it, is imperfect, and ought not to be practiſed.

But it may not be improper, to advertiſe the reader, that there is one thing abſolutely neceſſary to be taken notice of, in obſerving with any of the foregoing inſtruments, *viz.* that the plate muſt lie always parallel, or very near parallel to the plan of the horizon.

Likewiſe, he ought to allow for the difference between aſcending and deſcending lengths, when compared with the horizontal length.

For it is evident, that the length meaſured up an aſcent, or down a deſcent, will be always greater than the horizontal lengths, which only are the meaſures that ought to be entered, either for caſting or for drawing the plans of any parcel of land whatſoever; ſince theſe aſcending meaſures, if laid down, would crowd the adjacent ones out of their places.

And ſince theſe things are required very frequently, many times in going upon one aſcent, and conſequently ought to be performed in the field, in order to make a proper entry in the book; I would have the practitioner be provided with ſuch a *Theodolite*, as will perform without compaſſes, rulers, ſectors, tables, *&c.* theſe uſeful practices, or without any further obſervations than what is required to take the angle only. Such *Theodolites* may be made, not only to perform theſe, but alſo to ſhew by inſpection, the height of any ſtanding ſtick of timber, without any calculation, tho' the ſtick ſtood on level, riſing, or falling ground: Or the length of any arm out of reach; or height of any ſteeple or hill: Or by it a level proper for the conducting of water; very uſeful for all ſurveyors in general.

Tho' I do deſign to give a ſpecimen of this improved inſtrument, hereafter, in all its

conveniencies, I could not paſs it by in this place, leſt the reader ſhould over-look it.

In this place it will be proper to obſerve ſome particulars which experienced ſurveyors have found neceſſary.

In taking the *Theodolite* thro' a hedge, it ſometimes happens, that a thorn or ſprig catching the horſe-hairs in the ſights, breaks them; therefore the ſurveyor ſhould have ſpare horſe-hairs ready, and a piece of dry ſtick to cut to a ſharp point, to fix freſh horſe-hairs to the ſights.

In running the chain along a field where are many furze-buſhes, thorns, or other ſhort ſtuff, (or by other accidents) the links will be frequently bent, and the rings opened, whereby the chain parts; in ſuch caſe, a ſmall hand-viſe, and a pair of nippers ſhould be ready, that the chain may be put together again, the rings cloſed, and the links ſtraitened: And leſt ſome of the links ſhould be broke, or the rings loſt, there ſhould be ſpare links and rings at hand. One of the chain-men may eaſily carry theſe articles in his pockets: And it will be proper that one of them ſhould every evening, or the morning before he goes into the field, examine the chain from end to end, and rectify what may be found amiſs.

In cloudy dark weather, or towards the evening, the ſtation-ſtaves cannot be eaſily ſeen, unleſs at ſhort diſtances; and as it is much better on all accounts, to have them at long diſtances when that can be had, and is a loſs of time to ſet intermediate ſtaves; therefore if pieces of tin, or other white marks were ready to fix to the top of the ſtaves, the ſurveyor would find his account by ſuch precautions.

It often happens, that the glaſs which covers the box is wetted by rain, miſt, dews, or your breath; now in wiping this off to ſee the needle, the glaſs by being rubbed becomes electrified, and thereby attracting the needle, prevents its free motion: It is neceſſary the ſurveyor ſhould be apprized of this, and that by touching the glaſs with his finger wetted, over the place to which the point of the needle adheres, it will be releaſed from the electrical attraction, and move towards the poſition into which its magnetical virtue directs it.

An induſtrious ſurveyor will not leave the field for a ſmall, mizling rain; and altho' he cannot then write in his book with ink, yet his obſervations may be entered with a black-lead pencil, and theſe wrote over with ink when he returns to his abode.

There are ſeveral things that occur in a ſurvey, which cannot with convenience be entered in the field-book by the foregoing directions, ſuch as, places where are many buſhes, pits, or other obſtructions where the inſtrument and chain cannot be readily directed; alſo the ſite of houſes, barns, yards, ponds, *&c.* Such things ſhould be entered in the field-book by a ſketch or drawing in the oppoſite page, and ſuch lines meaſured with the chain or off-ſet-ſtaff, as are neceſſary to furniſh the means of making a true plan thereof.

Obſervations and Dimenſions of Lands lying in the Pariſh of——— in the County of ——— Part of the Eſtate of ———

February *the* 2*d*, 1725.

Beginning at the lane leading from Hardly *to* Roughton.

		⊙ 1	
		° ′	
		B 327. 00	
On Lord Title	20	0	20 On *Will. Wary*
Hedge to Lord			*Hedge to Wary*
ag. Hedge	20	65	25 *ag. Hedge*
On *Woodfield*			On *Hazle-ſpring*
Hedge to Field			*Hedge to Spring*
	40	345	50
	00	520	
		540	50
	40	800	00
		825	

		⊙ 2	
° ′			
327. 00			
180. 00			
507. 00		° ′	
304. 15		7 202. 45	
202. 45		*B* 304. 15	
	15	240	
		250	10

304.

° ′		⊙ 3	
304. 15			
108			
484. 15		° ′ ∠143. 45	
340. 30		B 340. 30	
143. 45		250	Gate
		260	10 *Corner*
	20	270	
340. 30		R ⊙ 4	
180			
520. 30			
261. 10		7 259. 20	
259. 20		B 261. 10	
Corner	10	15	
On *Long Mead*			
Hedge to *Long Mead*			
	15	220	
261. 10		⊙ 5	
180			
441. 10		∠156. 50	
284. 20		B 284. 20	
156. 50			
	10	165	10
284. 20		⊙ 6	
180			
464. 20		7 206. 50	
257. 30		B 257. 30	
206. 50			
	10	230	10 *againſt Hedge*
			On Spring Cloſe
			Hedge to Spring Cloſe
		240	

		R ⊙ 7	
257. 30			
180			
437. 30		7 264. 30	
173		B 173. 00	
264. 30		10 *Int.*	
	In	*Spring*	*Close*
			On *Hazle Spring*
			Hedge to Spring
		135	⊙7
		245	15
173. 00		⊙ 8	
180		7 202. 15	
353. 00		B 150. 45	
150. 45			
202. 15		154	11
		335	50
		550	35
		720 *Int*	00 *Corner*
	In William	*Wary's*	*Land*
		825	
150. 45		⊙ 9	
180		7 240. 00	
330. 45		B 90. 45	
90. 45		90	20
240. 00		110	05
		640	70
		755	15
		830	43 *Corner*
	* *Close*	*Hazle*	*Spring*

Taken

Taken from ⊙ 6	⊙ 7	
° ′		
257. 30	° ′	
180	∠ 162. 45	
437. 30	*B* 274. 45	
274. 45		
162. 45	40	*Gate*
15	230	05
50	230	
35	260	
	350	10 *againſt Hedge and Corner of Spring-cloſe*
R	⊙ 10	
	∠ 180. 00	
	B 274. 45	
	0	On *Tho. Coles*
30	60	
20	100	20
00	160	40
	⊙ 10	
274. 45		
180	∠ 246. 25	
454. 45	*B* 208. 20	
208. 20		
246. 25	10 *Int.*	
In *Tho.*	*Cole's*	*Land*
		Hedge to Spring Cloſe
	300	100
	340	10
	370	

	⊙ 11	
° ′		
208. 20	° ′	
180	∠ 208. 20	
388. 20	B 180. 00	
180	00	18
208. 20	630	15 *Corner*
	610	
	⊙ 12	
180. 00	∠ 275. 00	
180. 00	B 85. 00	
360. 00	20	*Corner*
85. 00		*on Spring Close*
275. 00		*Hedge to Spring-close*
	400	00
	870	20 *Corner*
		Close-spring-close
	⊙ 4	
Taken from ⊙ 3		
340. 30		
180	∠ 167. 15	
520. 30		
353. 15		
167. 15	B 353. 15	
On *Woodfield*	10	10 *Corner of*
Hedge to Woodfield		*Long Mead*
		Hedge to Long Mead
Gate 20	440	00

	R	⊙ 13	
° ′		° ′	
353. 15		∠ 91. 15	
180		B 82. 00	
533. 15		20 *Int.*	
82. 00			In *Woodfield*
451. 15		20	15 *Corner of Hazel-*
360			*(Wood*
91. 15			*Hedge to Wood*
		550	15
		⊙ 14	
82. 00		∠ 99. 00	
180		B 163. 00	
262		00	10 *Gate*
163			On *Wood-Close*
99			*Hedge to Woodfield*
		550	30
		⊙ 15	
163. 00			
180		∠ 249. 45	
343		B 93. 15	
93. 15			
249. 45		35	00 *Corner*
		430	130
		600	100
		610	50 *againſt Hedge and*
			Corner of Woodfield.
			On Lord Title's Land
			Hedge to Title
		835	10 *Corner*

		⊙ 16	
° ′		° ′	
93. 15		∠ 77. 35	
180		B 195. 40	
273. 15		00	00
195. 40		320	210
77. 35		500	00
		650	135 *Corner*
		742	
		⊙ 17	
195. 40		∠ 129. 10	
180		B 246. 30	
375. 40		00	15
246. 30		610	15 *Corner*
129. 10			*Close Woodfieta*
		⊙ 13	
		∠ 180. 00	
		B 353. 15	*On Long Mead*
againſt Hedge	20	20	*Hedge to ditto*
On Hazle Wood			
Hedge to Wood			
	25	140	00
		⊙ 18	
353. 15			
180		∠ 182. 45	
533. 15		B 350. 30	
350. 30			
182. 45	10	360	20
	10	445	20

		⊙ 19		
° ′				
350. 30		° ′		
180		∠ 168. 30		
530. 30		B 2. 00		
2. 00				
528. 30				
360				
168. 30	00	100	20	
	25	255	05	
	25	350	00	
	15	440	10	
	10	520	20	
	30	595	30	
	30	663	70	
		⊙ 20		
2. 00		7 234. 20		
180		B 307. 40		
182. 00				
360				
542. 00				
307. 40				
234. 20				
Gate	75	60		
	30	170		
againſt Hedge	20	215	00	
On Butts Cloſe				
Hedge to Cloſe				
	00	450	20	

		⊙ 21	
307. 40		° ′	
180		7 200. 40	
487. 40		B 287. 00	
287. 00			
200. 40			
	20	150	
	20	260	
	75	275	
		380	*Gate*
	70	400	
			00 *againſt Hedge and*
			Corner of Long Mead
			On Walter's Meadow
	25	510	
287. 00		R ⊙ 22	
180		7 280. 40	
467. 00		B 186. 20	
186. 20		10 *Int.*	
280. 40			*In Walter's Meadow*
		27	110 *Corner*
			On Long Mead
			Hedge to Long Mead
		360	15
		540	190
		735	10

		⊙ 23	
° ′			
186. 20		° ′	
180		∠ 200. 05	
366. 20		*B* 166. 15	
166. 15			
		10 *Int.*	
200. 05			*In Long Mead*
			Here Trout Beck
			River becomes the
Corner	10	20	*Fence.*
On Trout Beck			
Common Mead	00	50	*River* 40
	10	150	
	10	235	
River 40		245	
		⊙ 24	
166. 15			
180			
346. 15		∠ 235. 15	
111		*B* 111. 00	
235. 15			
	10	40	
	20	105	
River 50	00	255	
	25	345	
River 40		460	
		R ⊙ 25	
111. 00		∠ 61. 40	
180		*B* 229. 20	
291			
229. 20			
61. 40	30	80	30
	30	120	
		150	35
	25	160	
		170	50
	10	200	40

		⊙ 25	
° ′		° ′	
111. 00		7 128. 30	
180		B 162. 30	
291			
162. 30			
128. 30			
	15	145	
River 30	50	190	
	10	430	
	30	535	
		585	
		⊙ 26	
162. 30			
180			
342. 30		∠ 91. 00	
251. 30		B 251. 30	
91	45	70	
River 40	00	175	
		270	
		⊙ 27	
251. 30			
180			
431. 30		∠ 141. 00	
290. 30		B 290. 30	
141. 00		0	River 60
	67	205	
River 30	70	280	
	15	360	
River goes off		at	this place

° ′		⊙ 28	
290. 30			
180		° ′	
470. 30		∠ 291. 00	
179. 30		B 179. 30	
291. 00			
	10	00	
On *Tho. Cole's*			
Hedge to Cole			
	10	150	
	20	300	
	10	400	
	10	510	
			Close Long Mead
		⊙ 22	
		∠ 180. 00	
		B 287. 00	
	In	*Roughton*	*Common*
Corner	00	30	
		65	
287. 00		⊙ 29	
180			
467		∠ 104. 50	
2. 10		B 2. 10	
464. 50			
360			
104. 50			
On But's Close			
Hedge to Close	86	230	
	00	480	
	65	635	

° ′		⊙ 30	
2. 10			
180		° ′	
		∠ 89. 00	
182. 10		*B* 93. 10	
93. 10		65 *Int.*	
19. 00	*In*	*But's Close*	
			On Roughton Com.
		100	65 *Hedge to Close*
		350	100
		750	100
		835	15
93. 10	*R*	⊙ 31	
180		∠106. 00	
273. 10		*B* 167. 10	
167. 10		0	20 *On Home-Close*
			Hedge to Home-Close
106. 00		590	15
167. 10		⊙ 32	
180		∠126. 40	
347. 10		*B* 220. 30	
220. 30		0	10
		85	10 *against Hedge*
126. 40			On *Hazle Wood*
			Hedge to Wood
		415	10
			close But's Close
		⊙ 31	
		∠180. 00	
		B 93. 10	
		20 *Int.*	*Gate*
		In Home	*Close*
			On Roughton Com.
		195	30
		195	75
		750	10

	R	⊙ 33	
° ′		° ′	
93. 10		∠ 92. 40	
180		B 180. 30	*On Mottle Mead*
273. 10		00	*Hedge to Home close*
180. 30			
92. 40		625	15 *againſt Hedge*
			On Hazle-Wood
			Hedge to Wood
180. 30		735	20
180		⊙ 34	
360. 30		∠ 122. 10	
238. 20		B 238. 20	
122. 10		00	10
		310	10
238. 20			
180		⊙ 35	
418. 20		∠ 109. 50	
308. 30		B 308. 30	
109. 50		00	10
		485	10
			close Home-Close
Taken from ⊙ 31		⊙ 33	
93. 10		∠ 171. 10	
180		B 102. 00	
273. 10		20 *Int.*	
102. 00		*In Mottle*	*Mead*
171. 10		300	*On Roughton Com-*
		315	25 *(mon*

° ′		° ′	
102. 00		⊙ 36	
180		⁄ 200. 00	
282. 00		B 82. 00	
82.		70	65
200.		150	10
		380	60
		600	15
		770	15
		808	10
82. 00		⊙ 37	
180		∠ 136. 30	
262. 00		B 125. 30	
125. 30		00	15
136. 30		100	30
		260	30 *againſt Hedge*
125. 30		⊙ 38	
180		∠ 103. 40	
305. 30		B 201. 50	
201. 50		00	*On Ld. Title's Land Hedge to Lord*
103. 40		255	60
		270	
	R	⊙ 39	
201. 50		∠ 102. 30	
180		B 279. 20	
381. 50		00	30 *On Hazle Field Hedge to Mottle*
279. 20		295	35 (*Mead*
102. 30		605	15 *Corner*
		620	

		⊙ 40	
°		° ′	
279. 20		∠ 282. 05	
180		B 177. 15	
459. 20			
177. 15			
282. 05		370	10
		⊙ 41	
177. 15		∠ 85. 25	
180.		B 271. 50	
357. 15		00	15
271. 50		235	15
85. 25			
	R	⊙ 42	
		∠ 180. 00	
		B 271. 50	
		20	15 *againſt Hedge*
			On Hazle Wood
			Hedge to Hazle Wood
		375	15
			cloſe Mottle Mead
271. 50		⊙ 42	
180		∠ 268. 50	
451. 50		B 183. 00	
183. 00		15 *Int.*	
268. 50	*In*	*Hazle*	*Field*
On Hazle Wood			
Hedge to Wood			
	25	375	
Corner	10	760	
		790	

		⊙ 43	
183. 00			
180		∠ 153. 30	
363.		B 209: 30	
209. 30	270	230	
153: 30			
Corner	00	445 *Int.*	
	In	*Wood*	*Close*
	25	650	
Corner of Hazle Wood and Woodfield	30	860	
Taken from ⊙ 38		⊙ 39	
201. 50		∠ 196. 35	
180.		B 185. 15	
381. 50		30	20 *Corner*
185. 15		30 *Int.*	
193. 35	*In*	*Hazle*	*Field*
			On Ld. Title's Land
			Hedge to Lord
		400	165
		365	100
		1100	10
		⊙ 44	
		∠ 193. 45	
185. 15		B 171. 30	
180		200	110
365. 15		345	30
171. 30		440	70
193. 45		520	20

	R	⊙ 45	
171. 30		° ′	
180		∠ 81. 00	
351. 30		B 270. 30	
270. 30			
81		15	45 *On Wood Close*
			Hedge to Wood Close
		100	65
		340	95
		650	75
		740	80
		990	13
270. 30		⊙ 46	
180		∠ 112. 30	
450. 30		B 338. 00	
338. 00			
112. 30		00	10
		200	15 *ag. Hedge*
close Hazle Field			*On Hazle Wood*
		⊙ 45	
		∠ 180. 00	
		B 171. 30	
		15	10 *Corner*
		35 *Int.*	*On Ld. Title's Land*
			Hedge to Lord
	In	*Wood*	*Close*
		255	30
		300	

☉	☽
171. 30	
180	
351. 30	
251. 00	
100. 30	

☉	☽	
	⊙ 47	
	∠ 100. 30	
	B 251. 00	
25	100	
240	230	
330	175	
310	125	
640	00	
680	120	*againſt Hedge On Woodfield*

SECT.

SECT. VII.

To protract the obſervations contained in the preceding Field-Book.

FIRST, draw parallel right lines, as thoſe in Plate II. marked NS, repreſenting meridians or north and ſouth lines, at a diſtance from one another, not exceeding the breadth of the diametrical part of the *Protractor*.

Then picking out ſome convenient place to repreſent the firſt ſtation, as A; the field-book being open before me, I lay the center of the *Protractor* on the point A, and the diameter parallel to the lines NS, and the beginning of the degrees downwards, becauſe the bearing is more than 180; then againſt 327 degrees, I make a mark with my *Protracting Pin*, to which I draw an obſcure line from A, repreſenting the chain-line from the ſtation A to the ſtation B.

Then to this obſcure line, I lay the edge of my *Plotting Scale*, the beginning of the diviſions coinciding with A, and increaſing towards the next ſtation B, and becauſe the off-ſets, in the firſt length, are taken at the diſtances 65, 345, 520, 540, 800, 825; therefore, againſt theſe numbers on the ſcale, I make marks in the obſcure line cloſe to the edge of the ſcale.

This done, I turn my ſcale perpendicular to the obſcure line, and apply it ſucceſſively to theſe ſeveral points, and there prick off the lengths of the ſe-

ral offſets on their reſpective ſides of the obſcure line; ſo at A, I prick off 20 on the right hand, and 20 on the left; at the length 65, which is the next point, I prick off 25 on the right hand, and 20 on the left; and at the next point, which is at the diſtance 345, I prick off 50 on the right hand, and 40 on the left; at the fourth point, which is at the diſtance 520, I prick off 00 to the left hand; at the fifth point, which is at the diſtance 540, I prick off 50 to the right hand; at the next point, which is at the diſtance 800, I prick off 00 to the right hand, and 40 to the left; at the laſt point, becauſe no off-ſet was taken, I lay none down.

And now, if lines are drawn from point to point on each ſide of the obſcure line, they will repreſent the fences as was required. But when the off-ſet is 00, as in the fourth and ſixth diſtances, thoſe points, to prevent being over-looked, ſhould be marked with a black-lead pencil, or ſomething elſe, which may be eaſily rubbed out again.

At the ſecond diſtance, where we were againſt the ſouth fences of *Woodfield* and *Hazle Spring*, with a black-lead pencil draw two ſhort lines, cutting the lane, to denote that the ſouth fences come up to the lane, and will hereafter be of uſe in cloſing theſe plots.

Having thus finiſhed my firſt length, I produce it, if occaſion require from B, both ways, till it is as long each way as the *Radius* of the *Protractor*. Then I place the center of the *Protractor* on B, and thereon turn it about, becauſe the degrees of the next angle are more than 180, till the begnning of the degrees of the *Protractor* are contrary to the laſt ſtation A, and the diameter coincident with AB. Then cloſe to the edge of the *Protractor*, right againſt 202° 45′, I make a mark with my *Protracting Pin*, and to it from B draw an obſcure line repreſenting the chain-line from B to C.

Tnen

Then I turn the *Protractor* about, the center ſtill coinciding with B, and becauſe the bearing is more than 180, ſet the beginning of the degrees towards S, and the diameter parallel to the meridians; and then, if you have truly wrought, the line BC before drawn, will meet the limb of the *Protractor* againſt 304° 15′, the bearing of the line BC.

But if it doth not, the line BC is not in its true poſition, and muſt be corrected before you proceed.

Or thus; the center of the *Protractor* coinciding with B, I turn it about till the beginning of the degrees is towards S, becauſe the bearing is greater than 180, and till the diameter lies parallel to the meridians; and then cloſe to the edge of the *Protractor*, with my *Protracting Pin*, I make a mark againſt 304° 15′, the bearing of the line DC, and to it, from B, draw a ſtrait line repreſenting the ſtrait line BC. Then turning the *Protractor* about on the center C, and becauſe the angle there taken was 202° 45′, or more than 180, I turn the beginning of the degrees of the *Protractor* contrary to the laſt ſtation A, and the diameter to agree with AB; and then will BC meet the limb of the *Protractor* againſt 202° 45′, if the bearing is truly down.

And thus the plot may be laid down by the bearings, and examined by the angles.

Then to this obſcure line, I apply the end of my *Plotting Scale*, the beginning of the diviſions coinciding with the preſent ſtation B, and the numbers increaſing towards the next C; and then cloſe to the edge thereof, againſt 240, 250, the lengths where the off-ſets were taken, I make marks with my *Protracting Pin*. This done, I turn my ſcale perpendicular to the obſcure line, and at 240, I prick off 15 to the left hand, and againſt 250, which gives the point C, I prick off 10 the right hand, as the field-book directs. Now continuing the fences

to

to theſe off-ſets, I ſhall have finiſhed the ſecond length from B to C.

The ſecond length thus finiſhed, I produce it, if occaſion require, from C both ways, till the length each way be at leaſt equal to the *Radius* of the *Protractor*. Then I place the center of the *Protractor* on C, and becauſe the degrees of the angle at C are leſs than 180, I lay the beginning of the degrees of the *Protractor* towards B, the laſt ſtation, and the diameter on BC. Then cloſe to the edge of the *Protractor*, with my *Protracting Pin*, I make a mark againſt 143° 45′, the quantity of the angle at C, and to it draw an obſcure right line from C, repreſenting the line from C to D.

Then turn the *Protractor* about, its center ſtill coinciding with C, becauſe the bearing is more than 180, the beginning of the degrees towards S, and the diameter parallel to the meridians, and then if you have worked truly, the line CD before drawn, will meet with the limb of the *Protractor* againſt 340° 30′, the bearing of the line CD.

But if not, the line CD is not in its true poſition, and muſt be corrected before you proceed.

From the laying down theſe two angles and bearings, it appears how errors often happening in practice, may be prevented.

The general rules I obſerve herein are three, *viz.*

1. I lay the diameter of the *Protractor* on that line which brought me to the preſent ſtation, where the angle, about to be laid down, was taken.

2. I lay the beginning of the degrees of the *Protractor* towards the laſt ſtation, when the angle is leſs than 180 degrees; but the contrary way, when the angle is more.

3. In laying down or examining the bearing, I lay the beginning of the degrees of the *Protractor* northwards, when they are fewer than 180; but ſouthwards, when more.

In like manner I lay down and examine the angles and bearings taken at D, L, M, N, O, Q, the 4th, 5th, 6th, 7th, 8th, 9th ſtations, and alſo the correſponding lengths and occurrences. But in the laſt length QA, having at the length 830 laid off an off-ſet of 43, it gives exactly that corner of *Hazle-ſpring*, which was noted down in the firſt length in the lane; which proves that the angles and lengths incloſing *Hazle-ſpring*, are truly laid down. But if the extremity of the laſt off-ſet in the length QA doth not coincide with the extremity of the ſecond off-ſet AB, both denoting the ſouth weſt corner of *Hazle-ſpring*, the lengths and angles deſigned to incloſe the ſame *Hazle-ſpring*, are not truly laid down, and therefore muſt be examined and corrected before you proceed.

Now ⊖ 7, being marked with 7, a number not greater than 9, the number of the laſt ſtation, being the next work noted in my field-book; I return to ⊖ 7 in my draught, and there with MN, the line which I meaſured immediately before I came to N, I make the angle MNR 162° 45′, and the bearing NR 274° 45′, as noted in the field-book, and then proceed to lay down the off-ſets and other occurrences, at their proper lengths and diſtances.

Having finiſhed NR, I find next following in my field-book ⊖ 10, which becauſe it is greater than 8, the number which immediately follows 7, the number of the laſt ſtation; and becauſe I find no ſtation already laid down, marked with a number ſo great as 10, therefore I conclude, that the ſtation R, where I now am, is to be numbred 10; and from thence proceed

proceed to lay down and examine the angle and bearing at R, as uſual.

The rules I obſerve in theſe caſes are,

1. To number with black lead all the ſtations I have already laid down in my draught, and alſo to expreſs thoſe numbers ſucceſſively after one another, in a piece of waſte paper, which I examine as often as I pleaſe.

2. If I come to a ſtation whoſe number doth not immediately ſucceed the number of the laſt ſtation, but is greater than the greateſt of thoſe numbers noted in my waſte paper by an unit; then at the ſtation now arrived at, I lay down and examine the bearing and angle with the line I meaſured immediately before I came to this ſtation. And this ſtation I number as denoted in my field-book.

3. If I come to a ſtation, whoſe number doth not immediately ſucceed the number of the laſt ſtation, but is greater than the greateſt of thoſe numbers noted in my waſte paper by more than an unit, then ſome omiſſion hath aroſe in my waſte paper, and muſt be rectified before I proceed.

4. And laſtly, if I come to a ſtation whoſe number is already entered in my waſte paper, then I return to that ſtation in my draught, and there lay down and examine the bearing and angle with the line, meaſured immediately before I came to this ſtation, the firſt time.

Now the next obſervation I meet with in my field-book, is again ⊙ 10; therefore again at ⊙ 10, I lay down and examine an angle and bearing, as noted in the field-book, and then proceed to lay down

down the lengths and off-ſets of the line RS, as I find in my field-book.

Being come to S, I proceed to T, and from T to P, there cloſing with the extremity of the off-ſet at P, coinciding with the ſouth-weſt corner of *Spring-cloſe*, and the ſouth-eaſt corner of *Hazle-ſpring*.

This done, I find next in my field-book ⊙ 4; therefore I return to ⊙ 4, and there proceed as my field-book directs, till I come to ſtation 13; and becauſe this is a number greater, by an unit, than 12, the number noted in my waſte paper, I number it 13, and then proceed, as my field-book directs, to F, G, H, I, and K, there cloſing in *Woodfield* by the extremity of the off-ſets there laid down.

This done, I next find ⊙ 13, and therefore, becauſe already entered in my waſte paper, I return to ⊙ 13 in my draught; and then proceed as before ſhewn, till I have plotted all the occurrences mentioned in my field-book: But the remaining part hereof I leave for the exerciſe of the reader.

All houſes, barns, mills, or other buildings; alſo kilns, ſtone-pits, gravel-pits, ponds, watercuts, hills, hollow-ways, land-marks, bridges, roads, bridle-ways, foot-ways, ſtiles, remarkable old trees, and any other particular which the ſurveyor may meet with on the eſtate he is working in, ſhould be noted in the field-book; and ſuch meaſures, and ſketches of them taken, as that they may be inſerted in the plan: For ſuch particulars being frequently referred to in old terriers of eſtates, their being accurately delineated in a map, would aſcertain their poſition and diſtance from other places; and thereby prevent ſome of the fatal conteſts that ariſe among neighbouring families.

When all the particulars contained in the field-book are delineated or mapped, caſt up the contents of each incloſure, road, lane, waſte, *&c.* by the methods before ſhewn; and write the contents, together

with the name in each piece: Let the plans of buildings be ſhaded by lines drawn acroſs; and write the names of the neighbouring eſtates or pariſhes on the outſide, near the places where they bound the lands in your map; alſo at the ends of roads and lanes, write where they lead to and from; and thus will the foul draught of the ſurvey be finiſhed. This foul draught may be transferred to your clean paper, parchment or vellom, many ways; among which the following one is eaſily practiſed.

Take the ſcrapings of red chalk and black lead, in equal quantities, mixed together; rub the back of the map with this powder, and then wipe off as much as will come away with gently rubbing a cloth over it: Lay this coloured part downwards on the paper or vellom, faſtening them together with weights, pins, *&c.* Then with a ſharp-pointed bodkin or tracer, trace all the lines of the ſurvey, and the impreſſion of them will be marked on the vellom: Take the foul draught off, and go over all the coloured lines with a fine pen and Indian ink; and ſo will the draught be transferred.

Annex a ſcale of poles and yards; with a compaſs, allowing for the variation of the needle; alſo inſert the latitude of the church, manor-houſe, or ſome other noted mark; and embelliſh the map with ſuch other ornaments as are commonly introduced in works of this kind.

Obſerve that the repreſentation of the hedges ought to be laid down on the ſame ſides of the fences, that they are in the land; and to be broke off where there are to be the repreſentations of gates, *&c.*

There ought to be imaginary lines, both vertical and horizontal, denoted by letters placed at the top and bottom, and alſo on the ſides, to be referred to by the table of references; for the ready finding any field, or [illegible] land therein contained.

Laſtly,

Laſtly, I ſhall, in this place, only add, that in all performances of this kind, errors, for the moſt part, ariſe from the defects of inſtruments, in the framing, dividing, and contriving.

SECT. VIII. *

Of a new, certain, and expeditious Method of Surveying and Plotting by the Theodolite, *as now improved.*

IN the practice of ſurveying, it hath hitherto been found very difficult to make a large parcel of land, when it came to be laid down in a map, cloſe exactly with regard both to the lines and angles meaſured, eſpecially if it were mountainous and hilly ground, nay even a ſmall quantity of uneven land has often puzzled thoſe who otherwiſe thought themſelves expert ſurveyors. Now this difficulty in cloſing the draught, ariſes chiefly from the following cauſes.

Firſt, The not taking care to place the plane of the inſtrument truly horizontal or level, and which indeed it is almoſt impoſſible to do by the eye alone, eſpecially on the ſide of a hill; and tho' this may by ſome be thought of little ſignification, yet thoſe who have any knowledge in geometry, muſt allow, that very great and unavoidable errors will ariſe thereby; for it may be demonſtrated, that if the plate of the inſtrument dip but 2 degrees at right angles to the the line of obſervation, and the hill deſcend 10 degrees, it will cauſe an error of 42 minutes in the

* This Section is part of Mr. *Warner*'s Appendix to the ſecond edition of this book.

angle,

angle, and the object will be thrown out of its true place 12 links in the diſtance of 10 chains; and how great confuſion muſt this make in plotting the ſucceeding angles which turn thereon as on a center? But if ſo conſiderable an error ariſe by miſſing the level only 2 degrees, nearer than which I believe no one will pretend to place an inſtrument with by his eye, what egregious blunders muſt the practiſers with the plain table make, who, when they cannot ſee thro' the ſights of their inſtrument on an aſcent or deſcent, do commonly riſe, dip, or, as it may be properly ſaid, twiſt the plane of their table more or leſs out of the level till they can ſee their objects?

Secondly, The not making due allowance for the difference between the lines of aſcent or deſcent, and the horizontal lines, which are the only lines that ought to be laid down; and though it is a common practice on the ſide of a ſteep hill, to double the chain, and ſo in aſcending to make the leader hold the middle in his hand cloſe to the ground, while the follower raiſes the end by the ſtaff in his hand, till he judges it to be ſtrained on the level, and in deſcending, the leader elevates the middle by his ſtaff in like manner, while the follower keeps the end cloſe to the ground; yet a true horizontal line can hardly be obtained this way, by reaſon of the ſwaying of the chain, and the uncertainty of keeping it in its due place.

Thirdly, The plotting the angles by removing the Protractor from ſtation to ſtation; in doing which, if we conſider the nicety required in laying the diameter of the Protractor, and the variation of the hand in pricking down the quantity of degrees and minutes, and in drawing the ſtation-lines, we muſt allow it to be a very difficult matter to protract ſo near as 10 minutes; whence, if there be a conſiderable number of ſtations in the circuit, the plot will rarely be found to cloſe as it ought, for an error in

any

any one of the angles will be communicated to all that follow, and each ſucceeding ſtation will be thrown more and more out of its true place, as it is farther from the angle where the error firſt aroſe; and though it be a good way to protract backwards as well as forwards, yet even that will hardly bring it to bear, unleſs the errors happen to counterbalance.

The foregoing are the principal cauſes that render it difficult to make a correct map; and they are now intirely obviated by the *New Improved Theodolite*, as made by Mr. HEATH, and the method of ſurveying and plotting hereafter deſcribed.

Firſt, This inſtrument has a ſpirit-level affixed to the teleſcope, and another ſpirit-level at right angles thereto in the box; by means of which croſs levels, and the help of four ſcrews playing between two plates in the braſs head of the ſtaff, the plate or limb of the inſtrument is readily brought to a true horizontal ſituation.

Secondly, The teleſcope with croſs hairs therein, turns on an arch fixed to the index perpendicular to the plate of the inſtrument, the arch is of the ſame radius as the plate, and the teleſcope may be elevated or depreſſed thereon quite to a quadrant, or 90 degrees. On this arch are graduated the degrees of a circle, which are numbered from the vertex either way, with 10, 20, *&c.* and are cut by an index under the teleſcope, divided after *Vernier*'s (commonly called *Nonius*'s) way, like thoſe on the limb of the inſtrument. Within the degres are two lines numbered with 10, 20, *&c.* down to 100, and cut by the edges of the index; on the right whereof is graved *Elevation*, and on the left *Depreſſion*. Theſe lines ſerve to ſhew the altitude or depreſſion of any object in 100th parts of the diſtance at which the inſtrument is planted to take the obſervation, and are uſeful in finding the height of a tree in the meaſuring

of timber ſtanding; as alſo to find the altitudes of the ſeveral parts of a building in drawing the perſpective appearance thereof, as will hereafter be ſhewn. Below theſe are other graduations cut by the lower part of the index, which ſhew the difference between the hypothenuſe and baſe of any right-angled triangle, (the hypothenuſe being always ſuppoſed to conſiſt of 100 equal parts) and conſequently they give by inſpection the number of links to be deducted out of each chain's length in going up or down any hill, for reducing the hypothenuſal lines to horizontal. There are alſo plain ſights fixed upon the teleſcope to be uſed in ſhort diſtances, and for continuing the ſame ſtrait line both ways from the inſtrument, as is neceſſary to be done in many caſes.

When the index under the teleſcope is ſet to 00° at the vertex of the arch, and the two bubbles brought to the middle of their tubes, then the horizontal hair in the teleſcope cuts an exact level, and the plate of the inſtrument becomes a true horizontal plane; and if the interſection of the croſs hairs be ſet to any object by moving the teleſcope above or below the level, the diviſions on the vertical arch will ſhew the elevation or depreſſion of the object: Alſo, when the teleſcope is directed to any object, the inſtrument may be readily fixed ſo firmly in that direction, by turning a ſcrew under the center, that there can be no danger of being ſtirred by removing the index on the plate towards another object. The degrees on the plate are divided ſo accurately, that though they are cut by three indices 120° diſtant from one another, having *Vernier*'s (or as vulgarly called, *Nonius*'s) diviſions on each, yet the eye can perceive no inequality in the diviſions all round the limb, but whatever part of a degree the index under the eye-glaſs of the teleſcope cuts, the ſame will always be found to be cut by the other two; there is

alſo a ſmall index that ſerves to cut the particular diviſions on the limb to be uſed for taking the breadths in drawing the perſpective appearance of any building. The whole index, with the box fixed thereon, turns round on a conical center without ſtirring the needle, and may be fixed to any part of the limb, by means of a ſpring and ſcrew adapted thereto. In a word, the entire inſtrument is contrived ſo commodious, portable and ſtrong in all its parts, that it is allowed to be the beſt of the kind ever yet made.

Thirdly, In order to avoid any error that may ariſe in taking the angles in the field, or from protracting them angle by angle, as has hitherto been the univerſal cuſtom, let the ſurveyor obſerve this following method, which for its readineſs as well as accuracy, will, no doubt, be preferred and practiſed by all who would excel in this art.

The inſtrument being planted at the firſt ſtation, fix the index to 360 degrees on the limb, and ſetting the plate truly horizontal, turn it about till the ſouth end of the needle hangs over the *Fleur-de-lys*, or 360 in the box, and fix it in that poſition by help of the ſcrew underneath; then diſcharging the index, turn that about, and direct the vertical hair in the teleſcope, to cut the ſecond ſtation; there fix the index to the plate again, and the ſouth end of the needle will ſhew the bearing of the firſt line, which will alſo be cut by the index on the limb, and is to be entered in the field-book, as before ſhewn. Now when the inſtrument is removed and planted at the ſecond ſtation, obſerve that the index hath not been ſtirred, and turning the whole limb about, direct the vertical hair in the teleſcope back to cut the firſt ſtation, fix the plate in that poſition; then diſcharging the index, turn it about till the ſame hair cuts the third ſtation; there fix the index to the plate again, and ſet down the number of degrees and minutes it cuts on the limb, which number will at the

ſame time be cut by one end or other of the needle in the box, if there be no miſtake in the obſervation: Proceed in like manner at the third and all the following ſtations, always remembring after you have turned the plate about, and directed the teleſcope backwards, to obſerve that the index remains fixed at the degrees laſt noted in the field-book, ſo will the needle be always found to correſpond with the index ſufficiently near, to diſcover and prevent any error in the work.

We have here added an example of part of the field-book of an actual ſurvey, wherein the angles were obſerved by the method above deſcribed; and though there were 24 ſtations in the circuit, yet for proof, the inſtrument being planted again at the firſt ſtation, and the teleſcope directed back to the 24th, the plate being fixed in that poſition, the index was diſcharged, and the teleſcope directed to the ſecond ſtation, and then the index cut the ſame number of degrees as was firſt ſet down in the field-book.

When there is occaſion to return to ſome former ſtation, in order to go off from thence for the cloſing ſome particular part, as in the following example, we return to ſtation 23. Enter the number of ſuch ſtation again in the field-book, with a ſmall figure at the head of it, denoting how often the inſtrument has been planted at that ſtation, thus 23^{2} denotes the ſecond time of planting the inſtrument at ſtation 23; then conſider from which ſtation you looked forwards to the preſent ſtation 23, which was ſtation 22; ſeek in the field-book the bearing of the line between the ſtations 22 and 23, and fix the index to that number on the limb; then turning the plate about, direct the teleſcope back to the former ſtation 22, fix the plate in that poſition, and diſcharging the index, direct the teleſcope forwards to the next ſtation, and thence proceed as before; ſo will the needle be always found to be a ſure cheque

on

on the limb, tho' the obſervations do not depend thereon.

Note, *The letters affixed to the numbers of the ſtations in the following* field-book, *are not to be uſed in practice, being here added only for the more eaſy referring to the plot, in deſcribing the new method of laying down.*

The plan to which the following field-book refers, is in Plate III. By the mark × is underſtood an interſection, either acroſs a gate or fence. When againſt an off-ſet is put the mark +, and another number follows it, it means that both the numbers are to be laid off on the off-ſet line. ∠*r* ſignifies an angle or corner.

FIELD-BOOK of Part of the Manor of R, &c.

Remarks, Left.	Offsets Left.	⊙ s Bearings Lengths.	Offsets Right.	Remarks, Right.
		⊙ 1 (A)	- - -	*Upon Warley Common.*
		° ′		
Bearing - - - - -	- - -	43 : 20	- - -	N° E^{ly}
Hedgebuts to Kiln Wood	20	11		
Againſt Kiln Wood - -	27	59		
Hedge to ditto - - -	31	165		
		⊙ 2 (B)		
∠ + *laſt Bearing* -	- - -	204:40		
	30	175		
	15	280		
	30	400		
	21	560		
Hedgebuts to Furzfield	14	746		
		766		
		⊙ 3 (C)		
Againſt Furzfield - -		17 : 12		
	9	50		
	1	100		
	3	200		
	21	365		
		446	⊙ *for*	*cloſing Furzfield and entrance of the Lane to Brentwood.*
Hedgebuts to Furzfield	27	470		
againſt upper Poundfield	30	520		
		⊙ 4 (D)		
		195:50		
	46	140		
Hedgebuts to Woods Ga	41	255		
Depth of the Gard. 216				
Pound begins, and Fence-	48	500		
buts ends	46	527		
		560		

		⊙ 5 (E		
		268 : 20		
		50	×	*Gate into Pound Lane*
Lrs Pound - - -	15	65	37	*to Gate into lower Pound field.*
	7	97		
Woods House 30 deep	35	114		
	20	165		
		225	75	*Hedgebuts to Lower Poundfield againſt Pondfield.*
Lr of Woods Garden 113 deep, and Hedge buts to upper Poundfield	24	272		
		300	32	
		330	20	
	20	350		
Gate - - - - -	28	383	20	
		444	23	*Hedgebuts to Cowhouſe-field.*
	15	465		
	12	483	25	
		⊙ 6 (F)		
		107 : 50		
Gate - - - - -	6	58	26	*Gate.*
Hedgebuts to Upper Poundfield againſt little Boggyfield	12	155		
		200	29	*Hedgebuts to Cowhouſe-field againſt the Hop-pit.*
		222	16	
Gate - - - - -	42	238	- - -	*Gate.*
	6	300	22	
		⊙ 7 (G)		
		332 : 15		
	15	26	13	
		170	6	
Lane returns - - -	21	186		
		200	⊙	*for the Return* N° 32.
Lr againſt Gravel-pit-field	7	247	10 ×	*Gate into Moor's Barn-field.*
Hedge to Barnfield - -	7	267		

		⊙8(H)		
		166:20		
Ponds begin in Gravel-pit field	12	190		
	30	250		
	39	265		
	30	300		
		309		
		⊙ 9 (I)		
		324:35		
Ponds end - - -	40	27		
Gap - - - - - - - - -		118		
Fence changes to Gravel-pit field.	60	200		
	58	317		
	9	457		
	2	535		
	9	586		
Gate - - -		698		
From bye ⊙ at 330 in Line 11, 12.		⊙10(K)		
		40 : 50		
		20	34	× *Gravel-pit field Hedge into Ditto, againſt Home field Hedge to ditto.*
		165	45	
		380	12	
		520	24	
		744	58	*Hedgebuts to Dungfield Gate.*
		791	- -	
		⊙11(L)		
		225:45		
		67	64	
		84	75	
Alders		250	75	
		330	*bye* ⊙	*for the Alder Ground.*
		340	× *into*	*Alder Ground.*
		473	27	
		493		× *Hedge and Brook into Cumbers's Lane.*
		505		

	50	90	
	330	23	
319 *to* ⊙	388	- - ⊙	
N° 11.	100	6	
	280	0	
	315	30	
	351	- - ⊙	
	130	4	
	170	6	
	286	58	
	375	69	
	440	0	
10	480		
Kiln 195	494		
Field 120	550		
	568	× *Hedge & Brook into Cumbers's*	
	698	× *hilly Field Hedge*	
	720	*to* ⊙ 13	

		⊙ 12 (M)		
		355:50		
To the Brook - - -	24	90		
	46	157		
		178	111	*to Cumbers's Garden Hedge.*
	42	236		
	62	275		
			× *into*	*Cumbers's Alder Ground*
		308	45	*to Gate* + 60 *to* ∠*r Homsted.*
		347	51	*to* ∠*r Hillyfield Hedge.*
	75	357		
	75	427		
		480	× *into*	*Hillyfield.*
		535		
		⊙ 13 (N)		
		165:25		
To Hillyfield Hedge - -	43	77		
Againſt Alder Ground	42	100		
	50	117		
	60	170		
	53	267		
To Alder Hedge 45 +	45	312		
	11	396		
To Al. hedge 81 + *Corn.*	7	446	× *hin*	*field Hedge into Boggy-field.*
		489		
		⊙ 14 (O)		
		319:25		
To Alders - - - - -	30	13		
To Kilnfield Hedge - -	128	40		
To Alders - - - - -	25	120		
To hunting Gate 55 +	30	155		
Point of the Iſland 59 +	30	200		
		229		

		⊙ 15 (P)		
		179:55		
Againſt Iſland - - -	43	8		
Fence to ditto - - -	25	75		
	21	237		*Bogs.*
	37	345		
	25	464		
	16	484		
		⊙ 16 (Q)		
		33 : 20		
	17	50		
Corner - - -	13	188		
		⊙ 17 (R)		
		280:50		
Hedge to Boggyfield -	15	00		
Woodland ends - -	18	79		
	15	148		
		177		
		⊙ 18 (S)		
		347:50		
		19	×	*Boggyfield Hedge to Broomfield.*
Againſt Acre Bit - -	16	240		
		388		
		⊙ 19 (T)		
		27:25		
		74	×	*Acre Bit Hedge to dit.*
To Alders - - - -	40	150		
To Hedge - -	57	194		
		241		
		⊙ 20 (V)		
		256:35		
To Hedge 15 + - -	15	00		
25 + - -	10	100		

To Hedge - - - -	15	198	×	*Acre Bit-hedge into little Broomfield.*
Againſt woody Ground Hedge to lit. Broomfd.	19	260		
	50	383		
		⊙21 (W)		
		90 : 30		
	60	72		
Bogs - - - - - -	70	163		
	75	340		
		395		
		⊙ 22 (X)		
		290 : 10		
	49	20		
Againſt Kilnfield Gate - - -		176		
		⊙ 23 (Y)		
		104 : 00		
Corner - - - - $\bar{5}+$	14	35		
Againſt Kiln Wood Hedge to ditto	12	103		
		183		
		⊙ 24 (Z)		
		311 : 10		
	5	00		
	15	63		
	6	163		
	8	243	×	*Hedge into Warley Com.*
		263		*To ⊙ 1 where the ∠ from the laſt Bearing to ⊙ 2 was found to be 43° : 20′ as at firſt ſetting out.*
Return to - - - -	⊙	23² (Y)		*againſt Kilnfield Gate.*
		190 : 10		
		27	×	*Gate into woody Ground in Kilnfield.*
		100	35×	*out of Wood into field agſt Kilnwd H. to dit.*
		180	26	

		324	12	
		465	26	
		510	55	
		580	72	
		630	55	
		690		
		⊙25(a)		
		84:40		
		37	18	× *into Boggy Wood Hedge*
		80	15	*to ditto.*
		246	23	
		⊙26(b)		
		284:40		
		50	33	
		170	50	
		209		× *into Furzfield Hedge to dit.*
		224	53	
		⊙27(c)		
		105:30		
		100	27	
		190		*to Corner close Kiln Wood.*
Return to - - -	⊙	25^2 (a)	- - -	*in Kilnfield.*
		349:30		
		30	33	*against Boggy Wood.*
		90	15	
		280	37	
		396	- - -	*Hedgebuts to little Boggyfield.*
		424		
		⊙28(d)		
		252:50		
		34		× *Boggyfield Hedge into*
		120	45	*ditto.*
		200	42	
		291		

	⊙29 (e)		
	79 : 30		
	100	35	
Strait Hedge to Pound-lane - - -	161		× *Upper Poundfield Hedge into ditto.*
	190		
	⊙30 (f)		
	325 : 12		
	50	28	
	158		× *Furzfield Hedge into dit.*
	187		
	⊙31 (g)		
	184 : 00		
	35	30	*Corner.*
	65	45	
	300	25	
	428	*to* ⊙	27 *close Boggy Wood.*
Return to - - - - -	⊙ 100	31^2 (g) 80	
		314	⊙ *to*
Ret. to ⊙ *for the Return of Pound-lane at* 200, *in Line* 7, 8	⊙	32 (h) 68 : 20	*for closing Furzfield in Line* 3, 4. *againſt Gravel-pit field Hedge to ditto.*
		147	29	
		200	- - -	*Alders.*
Hedgebuts to little Boggyfield.	11	212	25	× *Gate into Kilnfield.*
		237	- - -	*Alders end.*
		306		
		⊙33 (i)		
		172 : 08		
Stile in Boggyfield Hed.	110	118		
	78	390		*Pond.*
	56	454		
	28	574		
	43	615		
		670	*to* ⊙	28 *close little Boggyfield.*

Return to - - - -	⊙	33² (i)		
		319:55		
		20		× *Gravel-pit-field Hedge*
		40	69	*into ditto againſt Ald.*
		173	40	
		200	0	
		320	11	
		400	45	
		500	45	
		535	25	
		600	27	
		629		
		⊙34(k)		
		232:05		
		43	5	
		106	5	
		144		
		⊙35(l)		
		141:35		
		56	6	
To Kilnfield - - -		627	10	*Cloſe Alders.*
Return to - - - -	⊙	23³ (Y)		*in Broomfield againſt Kilnfield Gate.*
		161:30		
		170		× *out of Wood into Kilnfield.*
Againſt Woody Ground	55	250		
	60	380		
		412		
		⊙36(m)		
		350:05		*Kilnfield.*
	72	70		
	68	230		
	15	300		
Corner - - - -	15	595		
		633		

		⊙37(n)		
		76:10		
	90	170		
		458		
		⊙38(o)		
		181:48		
Paſſage to Iſland - - -	30	50	×	*into Woody Ground.*
		165	×	*Rill.*
	45	256	85	× *into Iſland.*
	120	390		
		455	80	
	90	520		
		570	70	*Corner.*
	50	594		*To the Top of the Iſland.*
Return to - - - -	⊙	38² (o)		
		357:00		
		371	×	*Kilnfield Fence into rough Ground.*
		451	×	*Gravel-pit field Hedge into ditto.*
		473		
		⊙39(p)		
		235:55		
		348	15	*Railsbutt* + 61 *to rough Ground Fence.*
		474	15	*Kilnhouſe* 33 *deep* + 35 *to Fence.*
		519	16	
		674	26	*Workhouſe* 65 *deep.*
		707	27	
Cloſe Gravel-pit field		765	× *line*	32, 33 *cloſe Kilnfield.*

Now

Now to protract the foregoing obſervations, thro' the middle of the paper deſigned for the draught, draw the right line NS for a meridian, Plate III. and therein chuſe a convenient point C, to which lay the center of a circular protractor, the diameter coinciding with the line NS, and the 360, or beginning of the degrees being towards N the north, fix the protractor in that poſition by laying a weight thereon, or pinning it down; then on the circumference of the protractor prick down the ſeveral bearings noted in the field-book, numbering from the north eaſtwards, or towards the right hand all round, and to each point affix the number of the ſtation to which it belongs.

Chuſe a convenient place on the paper for the firſt ſtation, as at A, and laying the edge of a parallel ruler to the center C, and the point marked 1, open the ruler till the edge cuts the point A, and thereby draw an occult line parallel to C 1, on which ſet off the firſt length (165) from A to B, the 2d ſtation; then laying the parallel ruler to C and the point 2, transfer it to B, and thereby draw an occult line, on which ſet off the ſecond diſtance (766) from B to C, the third ſtation: Again, lay the parallel ruler to C and the point 3, transfer it to C, through which draw an occult line, and thereon ſet the third diſtance (520) from C to D the fourth ſtation. Proceed in like manner all round, and if the work be true, the laſt line will paſs through the firſt point; but if it doth not, and the error ariſes by miſtaking a whole chain or ſo, it may readily be diſcovered in which line it was committed by obſerving whether the laſt point fall ſhort of, or beyond, or above, or below the firſt point with which it ought to coincide.

The only ſeeming difficulty that can ariſe in drawing the ſtation lines by this method, will be to diſtinguiſh between an inſide and an outſide angle, though

though this can ſeldom be any obſtacle to the ſurveyor who took the dimenſions, and who by the idea he has of the land, will, for the moſt part, remember whether he turned off to the right or left at ſuch or ſuch a ſtation; yet, if he ſhould at any time doubt, as it may perhaps happen when he has ſeveral days work to protract, and a multitude of ſhort ſtations therein: Or, if any perſon who never ſaw the land, ſhould attempt to draw it out by the field-book, and find himſelf at a loſs about the quantity of an angle; then let him ſubtract the bearing at the next preceding ſtation from the bearing at the preſent ſtation in queſtion, increaſed by 360, if ſubtraction cannot otherwiſe be made, and the remainder gives the preſent angle; which if it be leſs than 180°, ſhews that the line flowing from the ſtation, muſt be drawn inwards, but if more, outwards. Thus at ⊙ 17 noted with R, it might be doubted, whether the line from thence ſhould be drawn inwards towards ſ, or outwards towards S; to ſolve which, from the bearing at the preſent ⊙ 17, 280° 50′, ſubtract the bearing at the laſt ⊙ 16, 33° : 20′, and the remainder 247° : 30′ being greater than 180 : 00, ſhews that the line muſt be drawn outwards towards S; the ſame doubt might alſo ariſe at ⊙ 18 (S), but if from the bearing at ⊙ 18, 347° : 50′, we ſubtract the bearing at the laſt ⊙ 17, 280° : 50′, the remainder 67° : 00′ ſhews it to be an inſide angle: Again, at ⊙ 19 (T) the bearing is 27° : 25′, to which add 360°, and ſubtract the bearing at the laſt ⊙ 18, 347° : 50′, and the remainder 39° : 35′ ſhews the preſent angle to be an inſide angle, and very acute.

When the draught is ſo large, that all the ſtations cannot conveniently be laid down about one centre, the firſt meridian line may be prolonged, or another drawn parallel thereto, in which the ſurveyor may make choice of a new centre where he ſhall think moſt proper, and round this he may place his remaining ſtations in like manner as before deſcribed;

and thus, he may chuſe as many centers as he ſhall find neceſſary, but the fewer he can diſpenſe with, the better.

Moreover, the bearings may be laid down by a ſemicircular protractor numbered, as it is commonly done, with a double row of figures to 360°, which ſome may rather chuſe to uſe, becauſe the limb thereof may be turned wholly towards the light, that ſo the diviſions may be more advantageouſly ſeen; but conſidering the edge of a protractor is always made very thin, there can be no advantage gained thereby; beſides the circular *one* is to be preferred in that it hath twice the room, and conſequently, when there is occaſion for laying down a great number of obſervations about the ſame centre, they will be leſs liable to confuſion. Again, the degrees on the limb of the inſtrument and in the box, may be numbered only to 180, and then begin again with 10, 20, *&c.* to 180 more, by which means that end of the needle which is next the eye, will always cut the ſame diviſion in the box as the index doth on the limb, and there will never be occaſion to enter a bearing greater than 180° in the field-book; ſo a ſemicircular protractor numbered with a ſingle row of figures, will ſerve to plot all the obſervations; but then there will be this great diſadvantage (as well as the foregoing in point of room) that, ſhould the ſurveyor forget whether any angle was more or leſs than 180°, he could not readily diſcover which to make uſe of; and ſhould a perſon, who had never ſeen the land, go about to protract the work from ſuch a field-book alone, he muſt be gravel'd at every ſtation where the angle approaches near 90° or 270°, as not having any means whereby to diſcover on which ſide it is to be formed, tho' this doubt may in ſome meaſure be prevented by noting the angle in the field by the mark ∠, or 7, according as it is within or without; yet ſhould the ſurveyor put down

down a wrong mark, or forget to enter any (which may eaſily happen when a multitude of obſervations are to be taken, and the weather proves untoward) in ſuch caſe a great deal of time may be ſpent before it can be aſcertained whether the angle be internal or external, which is very readily known in the former method; therefore *that* muſt be the moſt preferable, ſince it can never be ſubject to any ſuch inconvenience: And the practice thereof will be found ſo very eaſy to any perſon that underſtands the foregoing part of this book, that a farther explanation would be altogether needleſs.

But when the ſtation lines are plotted by the bearings, there never can ariſe any difficulty concerning which way the line is to proceed from the laſt ſtation; for as every ſtation line is to be drawn in a direction parallel to an imaginary line from the centre of the protractor to the direction in its circumference marked with the number of the ſtation; therefore its poſition is naturally aſcertained by drawing the line in that direction.

The figure in Plate IV. ſhews how the contents of the foregoing example of part of an actual ſurvey was caſt up; and here are likewiſe ſubjoined the dimenſions and calculations; whereby it may be ſeen, that notwithſtanding there are 10 ſeveral pieces meaſured ſeparately, yet when the whole plot was reduced to the trapezium MNOP equal thereto (by Prob. 10. page 8.) the content of this trapezium was found not to differ from the ſum of the ſeveral contents by half a pole, a confirmation of the truth ſurprizingly near.

Gravel-pit field with the ſmall parcel of Alders in the middle of it reduced to the △ *a b c.*

The baſe *a b* meaſured - -	1758
The perpendicular from *c*	1078
	14064
	12306
	17580
	18|9|5124

	A. R. P.
Area per Sect. 4.	9 : 1 : 36
Subſt. Ald. - -	0 : 2 : 14
Area of the field	8 : 3 : 22

The ſmall parcel of Alders in the middle of Gravel-pit field reduced to the △ *d e f.*

The baſe *d f*	655
Perpendicular from *e* - -	179
	5895
	4585
	655
	1|1|7245

	A. R. P.
Content - -	0 : 2 : 14

The Alder wood on the weſt ſide of Gravel-pit field reduced to the △ *g h i.*

Perpendicular from *h* - -	598
Baſe *g i* - - -	805
	2990
	47840
	4|8|1390

	A. R. P.
Content - -	2 : 1 : 25

Kiln field reduced to the △ *k l m.*

The baſe *l m* - -	1825
Perpendicular from *k* - -	1002
	3650
	182500
	18|2|8650

	A. R. P.
Content - -	9 : 0 : 23

Woody

Woody ground in Kiln field with the iſland reduced to the Trapezium *n o p q.*

The Diagon. *n p* 1120
⊥ from *q* 530 } *Sum*
⊥ from *o* 410 } 940

44800
1008
10|5|2800

A. R. P.
Content - - 5 : 1 : 02

Upper Pound Field reduced to the △ *w x y.*

The baſe *w x* - - 930
⊥ from *y* - - - - 464

3720
558
372
4|3|1520

A. R. P.
Content - - 2 : 0 : 25

Boggy-wood reduced to the △ DE*s.*

The baſe DE - - 955
⊥ from *s* - - - - - 480

76400
3820
4|5|8400

A. R. P.
Content - - 2 : 1 : 07

Little Boggy field reduced to the Trapezium *r s t u.*

The Diagon. *r t* - 752
⊥ from *s* - 380 } 680
⊥ from *u* - 300 }

60160
4512
5|1|1360

A. R. P.
Content - 2 : 2 : 09

Woods houſe and garden reduced to the △ ABC.

The baſe BC - - 375
Perpend. from A 197

2625
3375
375
17|3875

A. R. P.
Content - 0 : 1 : 19

Furz-field reduced to the △ FGH.

The baſe GH - 929
⊥ from F - - 336

5574
2787
2787
3|1|2144

A. R. P.
Content - 1 : 2 : 10

Kiln wood reduced to the △ IKL.

The baſe KL -	1441
Perpendic. from I	550
	72050
	7205
	7|9|2550
	A. R. P.
Content -	3 : 3 : 34

The whole plot reduced to the Trapezium MNOP.

Perpendicular from N -	1963
Ditto from P -	770
Sum -	2733
Diagonal MO -	2868
	21864
	16398
	21864
	5466
	78|3|8244
	A. R. P.
Content -	39 : 0 : 30

as on the right.

The CONTENTS.

	A.	R.	P.
Gravel-pit Field with the Alders - -	9	1	36
Alder Wood -	2	1	25
Kiln Field - -	9	0	23
Woody Ground -	5	1	02
Little Boggy Field	2	2	09
Upper Pound Field	2	0	25
Woods Houſe and Garden - -	0	1	19
Boggy Wood - -	2	1	07
Furz Field - -	1	2	10
Kiln Wood - -	3	3	34
Total—	39	0	30

SECT.

SECT. IX.

Of ſurveying of Shoals and Sands, by help of the New Theodolite.

THERE are three methods whereby this may be performed; for the obſervations may be made either on the water or on the land. Thoſe made on the water are of two kinds, one by the log-line and compaſs (as in plain ſailing) meaſuring the courſe and diſtance round the ſand; and then to be plotted as a large wood, or any encloſure taken by the circumferentor.

This method I omit for two reaſons; firſt, becauſe it is to be deduced from the writers of navigation; and, ſecondly, becauſe the diſtances thus meaſured are liable to the errors of currents, which generally attend ſhoals or ſands, that are near to the ſhore.

The ſecond method, where there are no diſtances to be meaſured on the water, tho' ſtill there is one inconvenience, common alſo to the former, becauſe the bearings or obſervations are to be taken on that unſtable element, (an error ſcarce mentioned by our practical artiſts) I ſhall briefly hint at; and ſo rather chuſe a third, which is liable to neither of theſe imperfections.

Let (in *Fig.* 30) a boat be manned out with a ſignal flag, a log and line, lead and line, and to obſerve the bearings of any land-mark, a compaſs with ſights:

Take two or more places, as A, B, C, on the ſhore, from whence the boat may be ſeen on the ſeveral parts of this ſhoal.

One of the boat's crew is to ſound till he finds himſelf on the edge of the ſand, by the depth of water, and then to come to an anchor; which he is to ſignify to two perſons on the ſhore, at B and C, by his ſignal. And then from thoſe known land-marks, B and C, the obſervers are to take the bearings of the boat, and to regiſter their obſervations; which, when done, they are to ſignify to the crew by waving a flag, or by ſome other ſignal.

And in the mean time, to prevent miſtakes, let the crew, take the bearings of each of theſe land-marks: Then weigh anchor, which ſuppoſe at D.

Then by ſounding, proceed to E, and make like obſervations. And ſo at E, F, G, *&c.* till you have ſurrounded your ſand.

And if in this proceſs, you are about to loſe the ſight of one of your land-marks, ſuppoſe C, let your aſſiſtant at C, who, at that time, will alſo be about to loſe the ſight of the boat by ſignals (before-hand agreed on) remove to ſome other object before-hand agreed on, ſuppoſe to H; and then to proceed as before.

Laſtly, if the ſand runs ſo far out to ſea, that the object cannot be ſeen by the boat, nor the boat by the obſerver on ſhore; there may be rockets fired by the boat's crew, and alſo by the obſervers on ſhore in the night, whereby thoſe bearings may be taken almoſt at as great a diſtance as the light can be ſeen. For ſuppoſing they riſe but a quarter of a mile above the apparent horizon, its ſtay will be about 9 ſeconds, and its diſtance for this quarter of a mile will be viſible about 44 miles.

But rockets riſe much higher, and then the diſtances are much greater, whereby they are viſible.

Or two boats may lay at anchor inſtead of the land-marks, and then you may work as before.

Now

Now, ſince the land-marks B and C are fixed, their poſition may be laid down in the draught, as in common ſurveying, by plotting the diſtance between B and C. And then, by plotting the line BD, and the line DC, according to their poſition, their common interſection, will give the point D. And in like manner E, F, G, *&c.* may be plotted; and ſo the ſhoal: And this from the bearings taken at B and C.

If this be a ſtanding lake, environed by bogs, not to be walked on; the obſervations at D, E, F, *&c.* by taking their oppoſites, may ſuffice to plot the ſame from the land-marks A, B, C, *&c.* as well as thoſe taken on the land; or, indeed, by the courſe and diſtance, as in navigation, if the water be ſmooth and without a current.

In ſea-ſhoals, it is convenient to note at each obſervation the depth of the water found by the lead, and the drift and ſetting of the current by the log and compaſs, while the boat is at an anchor, which may be done with eaſe and expedition enough. For while the boat rides at an anchor, her ſtern points out the ſetting of the current, and the log and glaſs will meaſure its drift.

And theſe ought to be noted on the draught, which may be thus:

The currents may be ſhewn, by drawing a dart pointing out its ſetting, and its drift by the Roman capital letters, and the depth of water by the ſmall figures.

All nocturnal obſervations ought to be ſeveral times repeated.

SECT.

SECT. X.

Of Water-Levelling, or the conducting of Water.

THE firſt thing neceſſary to this purpoſe, is the adjuſting of the level, which may be performed ſeveral ways: This that follows is very eaſy and natural.

Chuſe ſome ground which is not above 4 or 5 foot out of the level, for the diſtance of 8 or 10 chains length, and ſuppoſe it be AB (Fig. 31.) and find the middle between A and B, which ſuppoſe to be C; plant the inſtrument at C; direct the tube to a ſtation-ſtaff, held up at A, and elevate or depreſs the tube, till the bubble is exactly in the middle of the diviſions; then by ſignals direct your aſſiſtant at A, to raiſe or depreſs the vane, ſliding on the ſtation-ſtaff, till the horizontal hair in the glaſs, cuts the middle of that vane; then ſee how many feet, inches, and parts, are cut by the upper part of the vane, which ſuppoſe to be 3 foot 4 inches and 6 tenths.

In like manner direct to the other ſtaff at B, and ſuppoſe the upper edge of that vane to cut at the height of 6 foot 5 inches and two tenths; then will theſe two vanes be on a level.

From 6 foot 5.2 inches ſubtract 3 foot 4.6 inches, and reſerve the remainder 3 foot 0.6 inches.

Now, remove the inſtrument as cloſe to the higher ſtation-ſtaff as you can; ſo that the middle of the teleſcope may almoſt touch it. Then bring the teleſcope as near to a level as the judgment of the eye will direct.

Meaſure

Measure from the ground, the height of the top of the telescope; and also of the bottom, in feet, inches, and parts: Suppose them to be 4 foot 10.5 inches, and 5 foot 0.3 inches; then half the sum of these heights 4 foot 11.4 inches is the height of the centre of the glass; and to this add half the breadth of the vane, which suppose to be 1 inch and 5 tenths, and to the sum 5 foot 0.9 inches, add the preceding remainder 3 foot 0.6 inches; then let the person at B move his vane, till the upper edge cut 8 foot 1.5 inches, the sum of the preceding numbers.

Now, so elevate or depress the hair or the bubble, till the hair cut the middle of the vane at B, and at the same time the bubble stands in the middle of the divisions; and then will the instrument be duly adjusted.

If you have a mind to be curious, repeat the operation; but when you place the instrument at C, turn the tube at right angles to the line AB, and there set it level; then proceed with the repetition of the work. Only observe to cross-level it in this adjustment, and in all future uses whatsoever.

Or the level may be adjusted thus: As before, first plant the instrument in the middle between A and B (Fig. 32.) and observe the heights on the station-staves, which suppose to be as above; and consequently their difference, as before, is 3 foot 0.6 inches. Now measure from C towards the highest ground A, some distance that comes almost to A; suppose 4 chains to D, and DB will be 9 chains, and DA one chain: Then plant the instrument at D, direct the telescope to A, and, setting the bubble to the middle of the division, direct your assistant to move the vane, till the hair cuts the middle of it; and note down the feet, inches, and parts cut by the upper edge of the vane; which suppose to 3 foot 8.4 inches: To this add the difference

rence 3 foot 0.6 inches, and the ſum 6 foot 9 inches reſerve.

Now direct the teleſcope to the ſtaff at B, level it, and direct your aſſiſtant to move the vane, till the hair cuts the middle thereof; and then, if the upper edge of the vane cuts the foregoing ſum 6 foot 9 inches, the hair and bubble are truly adjuſted. But if not, ſay, As B D wanting A D, is to the difference between the numbers cut by the upper edge of the vane, and the number 6 foot 9 inches; ſo is the diſtance A D to a number, which added to that cut by the vane, when leſs than 6 foot 9, and ſubtracted from the number cut by the vane, when it is greater than 6 foot 9, will give a number, to which let the aſſiſtant fix the vane; then ſo elevate or depreſs the hair or the bubble, till the hair cuts the middle of the vane at B, and the bubble ſtands in the middle of the diviſions; for then the level will be adjuſted. The operation may be again repeated, and at every ſtation croſs-levelled, which will confirm the former adjuſtment.

After the inſtrument is duly adjuſted, you may proceed to uſe it. Let the example be this annexed, (fig. 33.) where A every where repreſents the level, and B the ſtation ſtaves; and ſuppoſe the rout be made from a to e; firſt plant the inſtrument between the ſtation ſtaves a and b: at A direct the level to a B, bring the bubble to the middle of the diviſions, and inſtruct your aſſiſtant ſo to place the vane, that the hair in the teleſcope cuts the middle of the vane; then in a book divided into two columns, the one intituled *Back Sights*, the other *Fore Sights*, enter the feet, inches, and parts cut by the upper edge of the vane at a B, in the column intituled *Back Sights*.

Then look towards the other ſtaff b B, bring the bubble to the middle of the diviſions, and direct your aſſiſtant to place the vane ſo, that the hair cuts the middle of the vane; then enter the feet, inches, and

parts cut by the upper edge of the vane, in the column of *Fore Sights*.

Now, plant the inſtrument at A^3, ſtill keeping the ſtaff Bb exactly in the ſame place, and carry the ſtaff a B forwards to the place c B; now look back to the ſtaff b B, and enter the numbers cut by the vane there, under the title *Back Sights*; then look forwards to c B, and enter the obſervation under the title *Fore Sights*. Do the like when the inſtrument is planted at A^3, A^4, *&c.* always taking care to keep the ſtaff in the ſame place when you look'd at it for a *Fore Sight*, till you have alſo taken with it a *Back Sight*.

Having finiſhed your level, add up the column of *Back Sights* into one ſum, and the column of *Fore Sights* alſo into one ſum; and the difference between theſe ſums is the aſcent or deſcent required. And if the ſum of the *Fore Sights* is greater than the ſum of the *Back Sights*, then e is lower than a; but if the ſum of the *Fore Sights* is leſs than the ſum of the *Back Sights*, e is higher than a. For example-ſake, let the numbers be as in the following table.

Back Sights.			*Fore Sights.*		
Feet.	Inch.	Tenths.	Feet.	Inch.	Tenths.
3	7	5	6	4	5
4	6	8	8	3	2
6	0	2	5	4	7
9	5	0	8	7	8
1	0	7	9	4	8
24	8	2	38	1	0
			24	8	2
			13	4	8

Hence the deſcent is 13 . 4 , 8

Now

Now follow ſome obſervations well worth notice.

I. If the ſum of the diſtances in taking the *Back Sights*, is equal to the ſum of the diſtances in taking the *Fore Sights*, all the minute errors of the inſtrument will mutually balance and deſtroy each other.

II. And if the diſtances thus taken are ſhort, the curvature of the earth may be rejected. For, if the diſtance from the inſtrument be every where about 100 yards, all the curvatures in a mile's work will be leſs than half an inch.

III. If the diſtances from the inſtrument to the hindermoſt ſtaff, be every where equal to the diſtance from the inſtrument to the correſponding ſtaff; the curvature of the earth, and the minute errors of the inſtrument will both be deſtroyed.

IV. If the diſtances of the inſtrument from the ſtaves, be very unequal and very long, the curvatures muſt be accounted for, and the diſtances, in order thereto, muſt be meaſured, either by pacing, by a chain, or a wheel.

V. For the more ready allowing for the curvature, you may obſerve, that the curvature for one mile, taken at one obſervation, is extremely near to 8 inches. And at all other diſtances, it is as the ſquare of 1 mile is to 8 inches, ſo is the ſquare of any other diſtance to the allowance for the curvature; that is, *Multiply the ſquare of any diſtance whoſe meaſure is taken in miles, by* 8, *and the product will give the allowance for the earth's curvature, in inches:* This curvature is always to be ſubtracted from the numbers taken off the ſtation ſtaff. Or if the diſtance be leſs than a mile, and taken by the four pole chain: *Square*

the

the chains, cut off 2 places to the right-hand, and divide thoſe to the left by 8, *and the quotient ſhews the inches and parts of inches to be allowed for the curvature.* Suppoſe the diſtance be 30 chains; then the ſquare of 30, that is, 900, when 2 places are cut off, gives 9,00 or 9, which divided by 8, gives 1 inch and 125 thouſandth parts of an inch.

VI. If theſe diſtances were taken by pacing, accounting 25 to the chain, the curvature may be found thus; *Square the paces, and double it, cut off 6 places to the left-hand, and thoſe to the right are the inches of curvature:* So, if the paces were 900, then from 810000 multiplied by 2, that is, 1620000, cut off 6 figures, and you have 1.62, the curvature to be allowed. To ſave the trouble of continual calculations you may uſe the following table, wherein the diſtances are in chains, and the allowance in inches, and 100th parts of an inch.

Diſtan.	Allowance	Diſtan.	Allowance
Chain	Inches	Chain	Inches
1	0,00125	27	0,91
2	0,005	28	0,98
3	0,01125	29	1,05
4	0,02	30	1,12
5	0,03	31	1,19
6	0,04	32	1,27
7	0,06	33	1,35
8	0,08	34	1,44
9	0,10	35	1,53
10	0,12	36	1,62
11	0,15	37	1,71
12	0,18	38	1,80
13	0,21	39	1,91
14	0,24	40	2,00
15	0,28	45	2,28
16	0,32	50	3,12
17	0,36	55	3,78
18	0,40	60	4,50
19	0,45	65	5,31
20	0,50	70	6,12
21	0,55	75	7,03
22	0,60	80	8,00
23	0,67	85	9,03
24	0,72	90	10,12
25	0,78	95	11,28
26	0,84	100	12,50

VII. Therefore it appears, that the beſt method to take a level, is to meaſure the ſeveral diſtances from the inſtrument to the back and forward ſtation ſtaffs; and enter them in the field-book, according to

to the titles of their ſeveral columns, as in the following example; and correct the heights from the table of allowances; which may be done at home, when you are about to ſum up the heights.

Laſtly, Though hitherto we have conſidered the level with one teleſcope only, the ſame obſervations may be applied to a level with a double teleſcope; and I would adviſe thoſe who uſe the double teleſcope, at every ſtation to turn that end of the teleſcope towards the ſpring, which, before was the contrary way.

Backwards.			Forwards.		
Diſtan. Links	Height Inches	Corrections Inches	Diſtan. Links	Height Inches	Corrections Inches
370	3,25	3,24	418	4,36	4,34
430	6,10	6,08	328	7,18	7,17
760	5,38	5,31	289	6,75	6,67
584	7,25	7,21	530	9,53	9,50
326	8,15	8,14	485	11,25	11,22
658	10,25	10,20	376	8,65	8,63
530	6,32	6,29	720	10,34	10,28
3658		46,47	3146		57,81
3146					46,47
68,04					11,34

So that the fall in 68 chains is about 11 inches and $\frac{1}{3}$ of an inch.

SECT. XI.

Of COLOURS.

IT is not worth while to ſpeak of the preparation of colours, becauſe they may be had ready prepared, at almoſt every colour-ſhop and fan-painter's, *&c.* Nor to mention but as many as are neceſſary and moſt fit for the ſurveyor. I judge thoſe to be the beſt, which are moſt tranſparent.

And for portability, I think liquids improper; therefore would rather chuſe thoſe colours, which, before tempered, are dry; whether in powder, or in lumps: And ſuch as require no other liquid to mix with them (than what is to be had every where) *viz.* fair water.

For *Gum Water*, with which many colours are mixed, is made by barely ſteeping *Gum Arabick* in fair water.

Carmine, a powder, mixed with *Gum Water*, is a beautiful red; may be ſhaded with ſome of the ſame, mix'd ſtronger; or with any reddiſh brown, or any ſadder red.

Carmine is chiefly uſed for drawing of red lines to repreſent the walls of gardens or other places; and alſo to colour the plans of buildings.

Ultramarine, a powder, mixed with *Gum Water*, is a moſt valuable blue, fit to ſhew ponds, lakes, rivers,

rivers, *&c.* it may be ſhaded with *Indigo Corns* ground with fair water on a white tyle, by the preſſure of a knife's point, and then mix'd with *Gum Water*.

Red chalk, a lump, ſometimes called *French Chalk*, ground by rubbing it on a tyle with fair water, and afterwards with *Gum Water*, ſlightly laid on, is proper to repreſent roads and pits; and is ſhaded by itſelf more ſtrongly mix'd.

Sap green, ſteep'd in water, is of itſelf a good green to colour trees.

Verdegreece, in lumps, diſſolved in vinegar, or in water, makes a greeniſh blue, or ſea-colour, very tranſparent.

Gumbooge, in lumps, ſteep'd in fair water, produces a beautiful and tranſparent yellow.

Yellow berries, ſteep'd in fair water, a yellow.

Verdegreece diſſolved, mixed with *Gumbooge*, or yellow berries, in different proportions, produces different greens, inclining either to the blue or yellow, according to the quantities of either uſed.

Indian ink is uſed in drawing the firſt lines of a draught, and in ſhading of hills and deſcending grounds: A proper quantity of it may be liquified when wanted, by putting a few drops of water on a cake, and rubbing it with the finger until the colour is as deep as deſired.

But there muſt be care taken in the uſing of Indian ink; *viz.* to have three or four different tints of colour prepared, of which the fainteſt is to be

laid on firſt, and ſo proceed to the deepeſt tint; alſo not to cover too great a ſpace at once; for if the margins are not ſpeedily waſhed off, the ink will dry in ſtreaks and ſpots, and look very ill.

Colours are laid on with hair-pencils; thoſe fit for moſt uſes, are about the ſize of a common writing quill, and the length of the hair, without the quill, not to exceed 6 or 7 tenths of an inch: In chooſing them take ſuch only as, when wetted either in your mouth, or in water, will, by ſtroaking them acroſs your finger, form a fine point, and are very ſpringy: And as moſt pencils have a hair or two at their point longer than the reſt, theſe may be taken off, by gently drawing the point, when the hair is wet, once thro' the border of the flame of a candle.

In the uſing of theſe pencils, it will be found convenient to have them fixed on ſmall ſticks about 6 inches long, one on each end; whereof one is to be uſed with colour, and the other with fair water, to lighten the margin of the colour, whereby it is inſenſibly graduated till it vaniſhes into the colour of the paper.

All colours are ſhaded by others of the ſame ſort, but of a ſtronger tint: and the manner in which they are uſed with the moſt facility and ſucceſs, is better gained by practice than by precepts.

SECT.

SECT. XII.

A farther uſe of the Theodolite *(as now improved); conjointly with the uſe of a Sliding-Rule aptly divided; to meaſure timber, either round, or hewn to a ſquare, or unequally ſquared. Alſo how to allow for aſcents or deſcents by finding the horizontal lines.*

THE principal difficulty in uſing this Sliding-Rule, is, in juſtly diſtinguiſhing the value of each diviſion. And in order to this, it may be obſerved, that the diviſions on this rule, may be diſtinguiſhed into three orders, *&c.* the longeſt, the mean, the ſhorteſt. And theſe different marks diſtinguiſh their value in a ten-fold proportion, in the ſame manner as the places of a number is diſtinguiſhed.

So that, if the longeſt repreſent hundreds, the mean will repreſent tens, and the ſhorteſt units.

And if the longeſt repreſent tens, the mean will repreſent units, and the ſhorteſt tenth parts.

Alſo, if the longeſt repreſent thouſands, the mean will repreſent hundreds, and the ſhorteſt tens; and in this caſe, the units muſt be eſtimated by the eye, in judging at diviſions, only ſuppoſed to be drawn, becauſe there is not room enough.

The longeſt diviſions are generally numbered by the figures 1, 2, 3, 4, 5, *&c.* and when they are numbered thus, 1, 2, 3, 4, 5, 6, 7, 8, 9; 1, 2, 3, 4, 5, 6, 7, 8, 9, 1; the line is called a double one. And when the longer diviſions are in number only

ten, and numbered 1, 2, 3, 4, 5, 6, 7, 8, 9, 1; or numbered 5, 6, 7, 8, 9, 10, 20, 30, 40, 50; or broken ſo as to begin at any other number, ſo as to contain only ten long diviſions; the line is called a ſingle one. And theſe are called *Gunter*'s lines, from the name of their author.

But we may obſerve, that although theſe diviſions repreſent equal diſtances; yet, from their uſe, they cannot be ſo. Nor will they be eaſily capable of an equal number of diviſions, in different parts of the rules; either of mean, between the longeſt, or of the ſhorteſt between the mean.

But in order to make this eaſy, here follows an explanation of the diviſions laid down on the Foot Sliding-Rule, which may eaſily be applied to other rules of greater length; where the multitude of the intermediate diviſions may be greater.

On the ſlider are two of theſe double lines, both alike; one of which moves againſt the fixed line above, which is alſo exactly like to either of the other; and the undermoſt line on the ſlider moves againſt a ſingle line, beginning with the numbers 5, 6, *&c.* and going on to 50.

If the firſt 1 be called an unit, the following numbered diviſions, till you arrive at the middle 1, will be units. And the mean diviſions will be tenth parts.

If the firſt 1 be called ten, the figures 2, 3, 4, *&c.* immediately following it, will denote 20, 30, 40, *&c.* And the mean diviſions, that is, the next longeſt in order, will denote units; the fifth of which is, for diſtinction, made longer than the reſt. And from 10 to 20, between each of theſe mean diviſions, the ſhorteſt denote each two tenth parts; becauſe the diſtances between the mean diviſions, are divided into five parts; but if the diſtances between theſe mean diviſions were divided by ſhorter lines into ten parts,

parts, which is ſeldom done on rules ſo ſhort, each would repreſent one tenth part.

In like manner from 20 to 30, that is, between the diviſions marked 2 and 3, the ſame order follows; ſave that the diſtances between the mean diviſions (becauſe of their nearneſs to one another) are divided into two parts only; and conſequently each of theſe ſhorteſt diviſions will denote five tenth parts; and the eye muſt eſtimate the other tenths not cut, but ſuppoſed to be cut between them: tho' in larger inſtruments, even here, and elſewhere, the ſhorteſt diviſions may be as many as thoſe between the 10 and 20.

This laſt multitude of diviſions, uſually continues to 40, 50, or perhaps farther, and are to be read as thoſe between 20 and 30.

But where the longeſt diviſions become cloſer together, as generally they do, between 80 and 90, and between 90 and 100, which, on the ſcale, is denoted by the digits 8, 9, 1, there are but two orders of ſub-diviſions; the greateſt ſtill keeping the ſame degree, and the other the next lower degree. And in this one example, the figured diviſions denote tens, and the other units.

But when the firſt 1 is called 100; then the figured diviſions will be accordingly 200, 300, 400, *&c.* The mean diviſions, or thoſe the next ſhorteſt, will denote tens. The ſhorteſt between 100 and 200, where the diſtance between the tens is divided only into five parts; I ſay, the ſhorteſt here will denote two units each of them; and the middle between theſe, will denote the ſingle units; which, if there had been diviſions, as in large inſtruments, would have been denoted by thoſe diviſions.

But from 200 to 300, from 300 to 400, and from 400 to 500, the diſtances of the diviſions repreſenting tens, are divided only into two parts, and conſequently, each of theſe ſhorteſt diviſions muſt re-

preſent five units; and all other units, either more or leſs than five, muſt be eſtimated by the eye, by ſuppoſing each of theſe diſtances cut into five parts. Nevertheleſs, in larger inſtruments, theſe diviſions may be cut and eſtimated as before ſhewn.

Towards the latter end of the line, the diviſions on theſe ſhort lines are ſo near together, that they ſcarce admit of three orders of diviſions, and conſequently (ſuppoſing the longer diviſions to denote hundreds, as in this example) the units muſt be eſtimated by the eye.

And in like manner, if the longer or figured diviſions denote thouſands, the lines of leſſer length will denote hundreds, the next inferior, tens, *&c.*

But becauſe, by inſpection, on this rule it will appear, that more than three places cannot be diſtinctly eſtimated; and, that thoſe are ſufficiently exact for all the uſes it is deſigned for; a farther diviſion, and conſideration thereon, are omitted.

If the firſt 1, that is, the beginning of the firſt line, denotes a unit; then the middle 1, or beginning of the ſecond line, denotes 10, and the laſt 1 denotes 100.

So, if the firſt 1 denotes 10; the ſecond 1 denotes 100, and the laſt 1000.

In like manner, if the firſt 1 denotes 100; the ſecond denotes 1000, and the laſt 10000.

And ſince, when the value of the firſt 1 of any line is known, the value of the other figures and diviſions are known alſo; therefore the latter line is to be read by the former directions. And thus are theſe three double lines to be read, as has been ſhewn, for the former.

But the ſingle broken line, which is on the fixed part of the leg of the rule, is not to be conſidered in this arbitrary manner.

For the longer diviſions have affixed to them their values, which ought to be conſidered as unvariable, unleſs

unleſs in ſome particular neceſſities hereafter to be taken notice of.

From the beginning of this line, to the diviſion marked 10, the diſtances of the longer diviſions, which are numbered 5, 6, 7, 8, 9, 10, are divided into 10 parts, by mean diviſions; and therefore, theſe mean diviſions denote tenth parts. And theſe mean diviſions are each ſubdivided by one ſhort line, each denoting therefore half of one tenth.

From 10 to the end of the rule, the diſtances between the longer diviſions, are each divided into 10 parts; and therefore each denotes units. And the diſtances between the units are each divided into 4 parts; therefore each denotes one fourth part of an unit.

In the double lines, let the diſtance between the 1 at the beginning, and the 1 in the middle, be called the firſt ſcale; and the diſtance between that in the middle, and the 10 at the end, be called the ſecond ſcale. The uppermoſt of theſe double lines is marked with the letter A, the next with B, the third with C; and the undermoſt, which is alſo called the girth-line, with D.

On the lines A and B, in the ſecond ſcale, there are placed the ſmall figures ^{12}, denoting an index fixed, tho' the value of the diviſions ſhould vary.

And, on the girth-line, againſt 12, is generally a hand or index for the like uſe.

The two upper lines are generally uſed for caſting up the ſurfaces of planks.

The two under ones for finding the ſolidity of timber.

Having thus far deſcribed and explained the reading of this rule; I ſhall proceed to ſhew its uſe in meaſuring planks and timber. But ſhall firſt ſhew the cuſtoms uſed in taking their dimenſions.

And

And firſt for planks; the buyer hath the liberty of meaſuring the dimenſions on that ſide of the plank he judges moſt advantageous to himſelf.

Then the length is meaſured either with two two-feet rules, or two-feet rules, and five or ten-feet rods.

The length is meaſured in feet and half feet, and, in ſome places, to quarters of feet.

Then lay half this length from the upper part, down towards the butt-end; where, with a piece of chalk, make a mark.

At that mark, or nearer the butt-end, if the buyer think it to his advantage, is taken the breadth, in inches and half inches.

If one ſide be wainy, the breadth is taken to the middle of the wain.

If both ſides are wainy, one wain is meaſured, the other rejected; and either of them as the buyer thinks fit.

Having thus got the length and breadth; call the firſt long diviſion on A, and alſo on B, each an unit. Then ſet the index on B, againſt the breadth in inches on A, and againſt the length in feet on B, will ſtand the content in feet on A.

EXAMPLE.

Let there be a plank, whoſe length is 24 feet and a half, and breadth 17 inches and a half; I demand the content?

Set the index (or 12, in the ſecond ſcale) on B, againſt 17 inches and a half on A, and then againſt 24 feet and a half on B, ſtands 35 and $\frac{3}{4}$ nearly on A; which is the meaſure of the plank required.

But when the feet, in length, on B falls beyond the end of the line A, then call the firſt 1 on A, a ten, and work as before ſhewn.

EX-

EXAMPLE.

If a plank be 45 feet and a half long, and 39 inches broad, what is the content?

Set the index (or 12) on B, againſt 39 on A, and 45 and a half on B, will fall beyond the upper end of A.

Therefore ſet the index on B, againſt 39 on A, taking in the firſt ſcale of A, becauſe the 1 on A is counted 10; and then, againſt 45 and a half on B, will ſtand 148 on A, the content required.

Theſe are all the varieties which happen in plank meaſure.

But notice may be taken, that from this content muſt be ſubtracted as much meaſure as will ballance all the viſible faults: and this is generally left to the judgment of the two meaſurers, and generally done before the contents are entered in the accounts, or indeed, before you paſs to another plank.

There are ſome differences in the cuſtoms of different countries, tho', for the moſt part, the foregoing are the moſt generally uſed.

The cuſtoms generally uſed in taking the dimenſions of timber, are not much different from thoſe uſed for plank.

For the whole length is firſt taken in feet and halves, then the middle is found and chalked, where, or nearer the butt-end, according as it is the buyer's advantage, the ſtick is girthed with a ſmall line, which is exactly quartered by twice folding; this quarter is meaſured in inches, halves, and quarters. And if the tree's bark is not peeled, as always happens in ſtanding timber; then from the foregoing girth muſt be made an allowance for the bark, which

is

is uſually thus: for trees girthing one foot, allow one inch, and ſo proportionally for all others. But for beech, elm, aſh, and ſuch as are thin barked, the allowance muſt be a ſmall matter leſs.

It is alſo to be obſerved, that, a ſtick is not called timber farther than it will hold half a foot girth. Alſo, that if there be any conſiderable arms which hold half a foot girth, they are alſo called timber, and meaſured as ſuch.

CASE I.

Having thus taken the length in feet, *&c.* and quarter girths in inches, *&c.* ſet 12 (the index) on the girth line, to the length on C, and then againſt the girth on the girth line, is the ſolid content on C.

EXAMPLE I.

Let a tree be 24 foot and a half long, and its quarter girth 17 inches and one fourth; to find the ſolid content:

Set 24 and a half on C, againſt the index on D, the girth line; and then againſt 17 and one fourth on the girth line, ſtands 50 three fourths on C, the ſolid content of the ſtick.

CASE II.

When, by the foregoing directions, the rule is ſet, and the girth on the girth line is beyond the upper end of C; call the firſt 1 on C 10; and then work as before.

EX-

EXAMPLE II.

Let a tree be 30 inches girth, and 40 foot and a half long; to find the ſolidity:

If you ſet 40 and a half on C, againſt the index on D, then 30 on D is beyond the upper end of C.

Therefore, calling the firſt 1 on C 10, ſet 40 and a half on C, to the index on the girth line D; and then againſt 30 on D, will ſtand 253 on C, the ſolidity required.

CASE III.

When the girths on D fall ſhort of the lower end of C; call the middle one on C, a unit; and then, all the figured diviſions, below the middle 1, will be tenth parts of feet; then work as above.

EXAMPLE III.

Let a ſtick be 3 foot long, and 6 inches girth; to find the ſolid content:

Accounting the middle 1 on C an unit, ſet 3 on C, againſt the index on D; and then, againſt 6 on D, ſtand 7 tenths and a half on C; the ſolidity required.

EXAMPLE IV.

Let a ſtick be ſeven foot and a half long, and girth four inches; to find the ſolidity:

Set the index (12) on D againſt 7 and a half in the ſecond ſcale on E; then againſt 4 on D ſtand

8 tenths and a third on C: ſo that the ſolidity is 8 $\frac{1}{3}$ part in 10 of one foot.

N. B. Tho' this is not what is called timber, yet ſince alders and other ſhrubs, uſed by turners and others, are often meaſured, be they never ſo ſmall; I thought it proper to inſert ſome examples of this kind.

In the three foregoing caſes, the girths of the ſticks fell on the girth line C, without any arbitrary alteration of the values affixed to the diviſions; which fixed values are abundantly ſufficient for computing the ſolidity of moſt ſticks uſually to be met with, if the ſingle line C be advantageouſly broken. For, if a perſon deſigns his rule for the meaſure of timber only, that is, ſuch as never girths leſs than ſix inches; then the girth line beginning at ſix, will run to ſixty inches: above which, few ſticks will out-run. But if he deſigns to meaſure alders, ſhrubs and ſmall things, *&c.* often meaſured by turners, wheelwrights, and other artificers, uſing this ſmall ſtuff, the beſt way is to have the line C broke, and to begin at 1 and a half, or 2, and end at 15 or 20, according to the ſize of the ſtuff they moſt deal in.

But that the line, as uſual or occaſionally broken, may ſerve for the computing of common timber, timber extraordinary large, out-running the girth line, and alſo for ſhrubs and ſmall twigs; it may not be amiſs to conſider the following directions and examples.

And in the firſt place, we will enquire into the uſe of the rule in computing the ſolidity of ſuch large ſticks, as out-run the affixed values of the diviſions on the girth line.

For which obſerve, that the length of a ſtick always to be found on the upper end of the line C, is to be ſet to the index; the diviſions on the girth line

line numbered 6, 7, 8, &c. are to be accounted 60, 70, 80, &c. and that, in eſtimating the ſolidity of the ſtick, the diviſions on C are to be eſtimated by 100 times the value arbitrarily taken thereon by the length: that is, if the ſecond ſcale of C be called units in the length; then, in the ſolidity, the ſame upper part ſhall be called hundreds, and the lower ſcale tens: in like manner, if the upper part of C be called tens in the length; then, in the ſolidity, the upper part ſhall be called thouſands, and the lower part hundreds.

EXAMPLE V.

Let there be a ſtick, whoſe length is twenty-five feet, and girth forty-ſix inches; and let forty-ſix be above the upper end of the girth line: to find the ſolidity.

Then ſet twenty-five in the ſecond ſcale of C, againſt the index on D; and then againſt (4 and 6 tenths on D, which in this caſe repreſents) 46 inches the girth, ſtands 367 foot on the firſt ſcale of C; eſtimated according to the preceding directions.

EXAMPLE VI.

Let there be a ſtick, whoſe length is four feet, and girth forty-ſix inches; and let forty-ſix be above the upper end of the girth line: to find the ſolidity.

Set 4 in the ſecond ſcale of C, againſt the index on D; and then againſt the girth 46, on the lower part of D (which, in this caſe, will be repreſented by the affixed value, 4 and 6 tenths) ſtands 59 feré on the lower part of C, eſtimated according to the preceding directions.

For very ſmall ſticks, whoſe girth falls below the beginning of the girth line D; obſerve, that the length of the ſtick always to be found on the firſt ſcale of the line C, is to be ſet to the index; the diviſions on the girth line numbered 10, 20, 30, *&c.* are to be accounted only 1, 2, 3, *&c.* And that eſtimating the ſolidity of the ſtick, the diviſions on C are to be eſtimated by the 100th part of the value arbitrarily taken thereon by the length; that is, if the firſt ſcale of C be called units in the length, then in the ſolidity, the ſame lower part ſhall be called hundredth parts only; and the upper end tenth parts. But if the lower end of C be called tens in the length, then, in the ſolidity, ſhall the ſame lower part be called tenth parts, and the upper end units.

EXAMPLE VII.

Let a ſtick be fifteen feet long, and let its girth be three inches; and let three be below the lower part of the girth line: to find the ſolidity.

Set 15 feet, taken in the firſt ſcale of C, to the index on D; and then againſt 3 (which, in this caſe, will be repreſented by 30) in the upper part of D, ſtands the ſolidity 9 tenths of a foot, and a quarter of another tenth.

EXAMPLE VIII.

Let a ſtick be three foot long, and let its girth be two inches; and let two be below the lower part of the girth line: to find the ſolidity.

Set 3 foot, taken in the firſt ſcale or lower end of C, to the index on D; and then againſt 2 (which, in this caſe, will be repreſented by 20) in the upper part

part of D, ſtands the ſolidity, eight hundredth parts of a ſolid foot, and ſomething more.

In thoſe places where the cuſtom allows the taking the length to minute parts of a foot; or when the length is leſs than one foot: take the dimenſions in feet, and decimal parts of feet.

Thus much for round timber; but when timber is hewn to that form which is uſually called ſquare, tho' at the ſame time there is moſt commonly four wanes; the cuſtom is to take the length, and find the middle in the ſame manner, and with the ſame allowances as were obſerved in round timber; and then, in this middle, either with a pair of callipers, or the edges of two rules applied to the flat faces, to take the breadth and depth of the ſtick. Then, to add the breadth and depth together, and to uſe half their ſum, as you before did the quarter girth of a round ſtick.

EXAMPLE.

Let a ſtick be twenty five foot long, fourteen inches broad, and twelve deep: to find the ſolidity according to this cuſtomary method.

Becauſe 14 and 12 give 26, whoſe half is 13, ſet 25 on C againſt the index on D; and then againſt 13 on D, ſtands almoſt 29 foot and a half ſolid.

And tho' this cuſtom makes the ſtick ſomething more than in fact it is, by adding the breadth and depth together, and taking their half for a girth; yet, in a whole tree, only hewn to a ſquare, the difference is ſo very ſmall, that the cuſtom may be admitted.

For in this example it may appear by the pen, that the ſolidity thus is $29\frac{49}{144}$ foot; and the true ſolidity, if the ſtick be all of the ſame bigneſs, and

without wanes, will be 29 $\frac{24}{144}$, differing from the former only $\frac{35}{144}$, or $\frac{1}{6}$ of a foot ſolid.

Nevertheleſs, in ſticks whoſe breadth differs very much from the depth; the error is intolerable, and ought not to be admitted.

For, let there be a ſtick 25 foot long, 20 inches broad, and 6 inches deep; then, by the cuſtomary way of adding the width and depth together, the ſolidity will, as before, be 29 $\frac{49}{144}$ foot; but the true ſolidity will be only 20 $\frac{120}{144}$: and ſo the error is 8 $\frac{73}{144}$ foot, almoſt a third part of the ſtick.

For the ready management of ſuch timbers, there may be placed on the other leg of the rule, another ſlider; having the ſliding part and the upper fixed line, exactly the ſame as in the former leg; but on the other fixed part, a double line of the ſame radius with the former, but broken and inverted. And as the lines on the former leg were diſtinguiſhed by the letters A, B, C, D, ſo the lines on the latter are noted by the letters E, F, G, H. And as the diviſions on the lines A, B, C, were intirely arbitrary, ſo the lines E, F, G, are alſo intirely arbitrary. And on the line H, which is inverted, and beginning at 1 and a half, and running on to 150, the values annexed to the diviſions, may be varied, or remain unvaried. But on the line E being direct, beginning at 1, and running on to 100, the values annexed to the diviſions, may be conſtant.

The line H, I call the depth line; the line G the breadth line; the line E, I call the length line, and F the content line.

The uſe is ſo ſhort and ſo eaſy, that, in a few words, and two or three examples, it will be plain.

For, ſet the breadth on G, againſt the depth on H, and then the length on E will ſtand againſt the ſolid content on F.

Let

Let the ſtick be that of the laſt example; where the length was 25 foot, breadth 20 inches, and depth 6 inches.

Set the breadth 20 on G, againſt 6 on H; and then, againſt 25 on E, will ſtand on F almoſt 21, the ſolidity required.

And, to avoid confuſion, remember, that whatſoever is the value of the diviſions on G, the ſame ſhall be the value of the diviſions on F. That is, if the former diviſion on G be units, and the latter tens, then the former diviſion on F ſhall be units, and the latter tens. And if the former diviſions on G be tens, and ſo the latter hundreds; then the former on F ſhall be tens, and the latter hundreds.

If the length on E falls beyond F, call the former diviſions on F, tens, and the latter hundreds.

If the length on D falls ſhort of F, call the former diviſions on E tenth parts, and the latter units.

EXAMPLE.

Let a ſtick hewn to unequal ſquare ſides, have its length 46 foot, its breadth 30 inches, and its depth 20 inches; then, when 30 on G is ſet againſt 20 on H, 46 on E will fall beyond the line F; therefore call the former diviſion on F, tens; and then ſet as before, and againſt 46 on E, will ſtand 191 $\frac{1}{3}$ on F, which is the ſolid content.

The ſhell, or flitch of timber, is readily caſt up by this rule; for, take the breadth on the flat ſide in the middle, and one half the depth in the middle, and work with the length and theſe, as tho' it were a ſquare ſtick, and you have the ſolidity ſufficiently near.

It is indeed true, that this is leſs than the true ſolidity; but in regard of its value it is thought enough.

Let there be a ſlitch, whoſe length is 30 foot, breadth 16 inches, and depth taken in the middle 4 inches. Set 16 upon G to 2 upon H, and againſt 30 on E, ſtands on F 6 foot and two thirds, the ſolidity required.

The ſawyers meaſure is done by one ſetting of this rule.

For ſet the number of kerfs or cuts on G, to the breadth of the boards on H, and againſt the length of the ſtick on E, ſtands on F the hundreds of feet ſuperficial.

EXAMPLE.

Let a ſtick, whoſe length is 30 foot, breadth 22 inches, and depth 20 inches, be ſo cut, that each board, with the waſte of the ſaw, may be 2 inches; that is, if it be cut parallel to the breadth, we ſhall have ten boards, and ſo 9 cuts or kerfs, and the breadth of each board will be 22 inches.

Set 9 on G againſt 22 on H, and then againſt 30 on E, ſtands 4.12 on F, that is, 4 hundred and 12 hundredth parts of 120, or another hundred.

Any plank or board, whoſe value is expreſſed in pence *per* foot, may be caſt up by this rule at one ſlip, without knowing the meaſure of it.

EXAMPLE.

A plank of walnut-tree is ſold at 2*s.* 9*d.* or 33 pence *per* foot, its length is 30 foot, its breadth 26 inches and a half.

Set the price in pence, 33 on G, againſt 26 and a half on H, and then againſt 30 on E, ſtands 182 on F, and a little more; that is, 182 ſhillings, or 9 pounds and 2 ſhillings.

It may be obſerved, that this ſliding rule is ſufficiently exact, and very ready for cubing ſtone; provided, that the two ſhorter dimenſions are taken in inches, and the longer in feet, and decimal parts of feet.

Alſo, that it may be applied to the cubing in feet, any ſolid in form of a parallelipipedon, whoſe content doth not conſiſt of more than 3 places.

And if a line be properly broken, and put on inſtead of H, it might be applied to digging, *&c.*

Or if the line H did ſlide as well as G, it might be applied to the meaſuring of all ſorts of parallelipipedons, by one ſetting of the rule, whether the anſwer be required in feet, or yards, or rods, *&c.*

It remains to ſay ſomething concerning the eſtimation of the meaſure of timber ſtanding.

And, firſt, we may obſerve, that, if we can get the dimenſions, the manner of computing, after an allowance for bark, is that already laid down.

But ſince we cannot always get all the dimenſions, we muſt take thoſe we can get at, and eſtimate the reſt.

And, firſt, we may obſerve, that the dimenſions in a tapering ſtick, which runs beyond timber, may be had thus: Girth the ſtick breaſt-high; to an 8th part of this girth, add three inches; and the ſum leſſened by allowance for bark, will give the girth in the middle. And for the length, meaſure from the ground ſo high as the tree runs timber, and then work as before.

EXAMPLE.

Let the girth breaſt high, be 6 foot, and length 40 foot; then, becauſe the 8th part of 6 foot is 9 inches, to this add 3 inches, and the ſum is 12;

from this deduct an inch for bark, and there will be left 11 inches; which, with the length 40 foot, gives 33 foot and a half for the ſolid content.

When the taper ſtick does not out-run timber at the top, the whole girth, at top, ſhall be added to the whole girth breaſt high; and an 8th part of this ſum ſhall be the girth in the middle; which, after an allowance for bark, ſhall be the girth to be uſed.

The uſual way of eſtimating the height of the tree, is, by applying to it a ten or twenty foot rod, and ſtanding at a convenient diſtance, and comparing the rod with the tree.

But the moſt certain method is by the *Theodolite*, as now improved, thus: Meaſure from the tree with a ten-foot rod 100 foot, level the *Theodolite*, and direct the teleſcope to the top of the tree; and then ſhall the teleſcope cut on the vertical arch (if the ground, from the tree to the inſtrument, be nearly upon a level) a certain number of feet; to which, if you add the height of the teleſcope, you will have the height of the tree.

But if the ground, from the tree to the inſtrument, be not quite level, then direct the teleſcope to the top of the tree, and note the feet cut by the teleſcope; and then direct the teleſcope to the bottom of the tree, and note the feet there cut.

And if one of theſe numbers of feet be above the level, and the other below, then their ſum is the height of the tree; but if both are above, or both below, then the leſſer taken from the greater, will give the height of the tree, without any other calculation.

When the ground, from the tree to the inſtrument, is very ſteep, take, with your off-ſet ſtaff, or five-foot rod, the height of the inſtrument above the ground, and at the ſame height on the tree above the ground the tree ſtands on, make a mark. Direct the teleſcope to this mark, and it will cut on the

the vertical arch among the diviſions of reduction, ſhewing the difference between the hypothenuſe and baſe, a number of feet which added to 100, will give the proper diſtance to plant the inſtrument from the tree; or, what is the ſame thing, it ſhall give a length on the aſcent, anſwering to 100 foot meaſured horizontally, very near.

The inſtrument being planted at this diſtance, work as before, and you will have the height of the tree correct.

Having mentioned this vertical arch, and its uſe in taking heights, I will now proceed to ſhew its farther uſes in ſurveying land.

If, in coming up an aſcent, or going down a deſcent, as ſoon as the inſtrument is ſet for obſerving the angle; you look on the vertical arch among the diviſions of reduction, you will find how many links, in every chain's length, this hypothenuſal line is to be ſhortened, in order to get the horizontal line, which ought to be laid down in your plan, and muſt be entered in your book.

And theſe diviſions of reduction are concentric with the diviſions of altitude and depreſſion, and alſo with the diviſions of degrees.

Laſtly, if the diſtance from the tree to the inſtrument be confined; then multiply the horizontal diſtance in feet, by the feet given by the inſtrument, and from the product, towards the right-hand, cut off two figures, and thoſe to the left, will be the height of the tree in feet.

SECT. XIII.

The uſe of the Theodolite, *in drawing the perſpective appearance of any building without meaſuring one ſingle line.*

THIS will admit of ſome variety; for either the picture is ſuppoſed to be parallel to one of the fronts of the module or building; or elſe oblique to both; and then is either in a poſition aſſigned, or in a poſition taken at pleaſure.

Firſt, ſuppoſe the picture parallel to one of the fronts; then plant the inſtrument and a ſtaff at any equal diſtances from the front, ſuppoſe 5, 10, or 15 feet; and direct the teleſcope to the ſtaff, and the needle will point out the bearing of that front: to this add or ſubtract 90 degrees, you will have the directing number; that is, the bearing of the line perpendicular to the front.

Now plant your inſtrument at the place, whence the original building is to be viewed. Bring the index to the beginning of the diviſions, and turn the whole inſtrument about, till the needle points at the directing number; and then ſcrew it faſt. Bring the teleſcope to the beginning diviſions in the vertical arch, and level the whole inſtrument: ſo will the inſtrument be duly ſeated and rectified for obſervation.

In order to get eaſily a due knowledge of perſpective in general, and particularly of the uſe of this inſtrument in drawing, turn to the figures in Plate V, and raiſe up the draught PK (Fig. 1.) perpendicular

pendicular to the plane of the leaf upon the line W K, and lift up the plane A Y W (Fig. 2.) till it is perpendicular to both the plan of the leaf, and alſo to the draught P K; then raiſe the draught A B W (Fig. 3.) till it coincides with A Y W, and conſequently will be perpendicular to the plane of the leaf, and alſo to the draught P K; ſo will the two draughts A W, P K, be the two fronts of the module, repreſented to the eye. Lift up the draught a V (Fig. 4.) till it is perpendicular to the plane of the leaf, and it will be the picture deſigned to be drawn; and will coincide with P K, the front of the module. T is the point on the ground whence the building is to be ſeen. Lift up E T, till the point E is perpendicularly over the point T: And E is the eye of the ſpectator, or the centre of the teleſcope. Now if you conceive ſtrait lines drawn from the eye at E, to the ſeveral points A, B, C, D, *&c.* in the module, they will meet the picture in the points a, b, c, d, *&c.* which are therefore the true appearances of thoſe original points A, B, C, D, and a line drawn from a to b, will be the true appearance of A B; and ſo of all other lines: for the rays of light come to the eye from the picture in the very ſelf-ſame direction that they would have come from the original module. Thus much by way of introduction.

Now, in order to draw the picture: Aſſign on your drawing board any point C, at pleaſure, for the centre of the picture; and draw C V the horizontal line, and perpendicular to it, the vertical line C X; from theſe two lines, all the parts of the building are to be laid down by their apparent diſtances from them.

N. B. *By the centre of the picture, I mean that point, whence, a line drawn to the eye is perpendicular*

to

to the plane of the picture. The horizontal line is that which paſſes thro' the centre, and is parallel to the horizon ; and therefore is the common interſection of the picture, with the plane of the ocular *horizon.*

The principal line in theſe draughts is, that coin, or that angle which is common to both the picture and the module ; and conſequently every where proportional to the building it ſelf : and is the firſt line to be laid down and divided ; which may be done thus : Let the example be as in the preceding ſcheme.

Direct the teleſcope to the point P in the building, and you will find the index on the horizontal plate of the inſtrument cut 32 foot and a half, and on the vertical arch 25 foot ; lay the latter above the horizontal line C V, perpendicular to it, from C to X ; and the former from C to x. Then, by help of the ſquare, draw x P, X P perpendicular to C V, C S, whence the perſpective appearance of the point P is found.

In like manner may be found the perſpective appearance of any point whatſoever, whether it be coincident to both the module and picture or not.

Depreſs the teleſcope to W, in the building, and (in this example) it will cut on the vertical arch 9 foot ; which, becauſe you look downwards, lay from x downwards to W in the picture, and ſo you have the true appearance of W. And conſequently, if you draw P W in the picture, you have the true appearance of the line P W in the building.

If you elevate the teleſcope to A′, in the building, it will cut on the vertical arch 15 foot ; which laid from x to A′ in the picture upwards, becauſe the point is above the horizontal line C V, will give the repreſentative of that point in the picture. And thus may every one of the points B′, C′, D′, *&c.* be laid down in the picture.

Direct

Direct the telescope to K′ in the building, and you will find on the horizontal arch, that the index cuts 69 foot and a half; which laid from C to L′, gives in the picture, the representation of the point L′.

Thro' L′, draw E′ L′ K′ perpendicular to C V, and A′ E′, B′ F′, C′ G′, *&c.* parallel to it, thro' the points A′ B′ C′, *&c.* and so the coins E K, and the tops and bottoms of the doors and windows may be limited in respect of their heights.

Direct the telescope to Q, and it will cut on the horizontal arch 38 foot and a half; which lay from C to Q′, and it will determine the appearance of Q′. In like manner may N′; and the jaumbs of the windows Q′ N′, M′ O′, be laid down. As also the other windows, doors, *&c.*

For the returned front a W, draw P C, W C, A′ C, B C, C′ C, D′ C, *&c.* and they will limit the heights of the parapets, facia's, windows, *&c.*

Direct the telescope to b, d, f, h, *&c.* and it will cut on the horizontal plate 16 foot, 17 foot and a half, 19 foot and one third, *&c.* - - - -, which laid from the vertical line X S, will give the breadths, representing the piers and windows.

The same may be done for the chimneys and their returns; or for any other lines, breaks, *&c.* And so the several parts of the perspective appearance of a building may be drawn without measuring.

That this compendium of perspective may be compleat, it may not be amiss to lay down the necessary *Theorems* in the most general manner possible; and herein I shall use those terms which Dr. *Brook Taylor* hath thought fit to mention, they being more comprehensive than such as are used by the other writers on this subject.

Theor. I. All the lines of any object (as in a module or building) which are parallel to one another, and

and to the picture; will be repreſented by parallels on the picture.

Theor. II. All lines parallel in the module or building, which are perpendicular to the picture, will, if continued, run to the centre of the picture. Tho' theſe parallels be or be not all in the ſame plane.

Theor. III. All lines in the module or building, perpendicular to the plane of the horizon, will be in the picture, perpendicular to the horizontal line. And theſe three *Theorems* are ſufficiently viſible in the preceding example.

Theor. IV. All lines in the module or building, parallel to one another, and to the plane of the horizon, but oblique to the picture (as in the following example, ſee Plate VI.) will meet in ſome one point in the horizontal line CV. Thus the parallel lines in the front W a, meet in the point V; and thoſe of the front PQ, meet in the point Y. Theſe points V and Y are (by Dr. *Taylor*) called the vaniſhing points of theſe parallels, and by him are thus found:

From T, the point repreſenting the place from whence the building is to be viewed, draw a line parallel to thoſe parallel lines in any front or face of the object; and where it meets the ground-line SR, draw a line RY perpendicular to SR, and its interſection Y with the horizontal line VY, will be the vaniſhing point required.

Theor. V. All the lines of an object which are parallel to one another, but oblique to the picture, and not parallel to the plane of the horizon, will be repreſented by lines meeting in a vaniſhing point, found by the interſection of the picture, and a line

drawn from the eye parallel to thoſe parallel lines. But this vaniſhing point will not be in the horizontal line, but either above it or below it.

Theor. VI. The ſhadows of all parallel lines made by the interſection of the ſun's rays, will, on the ground, be parallel; and conſequently in the picture, either be parallel, as in *Theorem* I. or elſe meet at a point in the horizontal line, as in *Theorem* II.

Now, as in the former example, the centre of the picture being determined, the parallels which were perpendicular to it, and alſo parallel to the plane of the horizon, were, by the help thereof, eaſily drawn; ſo in this example following, ſince the vaniſhing points are of no leſs uſe to draw all parallels, I ſhall, for this purpoſe, ſhew one general rule, without any exceptions; not in the geometrical manner ſhewn by Dr. *Taylor*, but by the help of the new *Theodolite*, as now improved by THO. HEATH, mathematical inſtrument maker, at the *Hercules* and *Globe*, near *Exeter-Exchange* in the *Strand*.

Let the example be that contained in Plate VI. where, as before, raiſe the draughts P Q, A Y W, A B W, (A W Y coinciding with A W B,) Fig. 1, 2, 3. and you have the module repreſented to the eye; raiſe the drawing a Q perpendicular to the plane of the leaf Fig. 4; and it is the plane of the picture deſigned to be drawn; but it is oblique to each front of the module: and the coin or angle P W is the only part of the module or building, which coincides with the picture. Raiſe up T E (Fig. 5.) as in the former example: and E repreſents the eye beholding the building or picture. Plant the inſtrument and a ſtaff in the line S W, which is the ground-line of the picture, or elſe at equal diſtances from it, that is, parallel to it. And

find,

find, as in the foregoing example, the directing number.

Plant the inſtrument at your deſigned ſtation T; and rectify it as in the preceding example. Aſſume the centre C, on the drawing board, draw C V, C X, as before.

Then lay down P W, and its ſeveral diviſions A', B', &c. and the two points a, b, as in the former example. Draw P a, and W b, and produce them till they meet: ſo ſhall their interſection V be the vaniſhing point ſought.

Uſe this point V as you did the centre of the picture in the preceding example; and then go on to draw the front a W as before.

In like manner find the vaniſhing point Y; and proceed to draw the front P Q.

As to the poſition of the picture, ſome perſons will have it parallel to a front, others parallel to the diagonal of the plane; others chuſe rather that poſition to which a line drawn from the eye to the common coin P W may be perpendicular to the plane of the picture.

And in this latter, there is no occaſion for the directing number, or the bearing of any front: for take T the ſtation at pleaſure; bring the index to the beginning of the degrees on the horizontal plate, and turn the whole inſtrument about till you ſee thro' the teleſcope the coin P W, there ſcrew it faſt, and level it; and proceed in all reſpects as in the laſt example.

SECT.

SECT. XIV.

The deſcription and uſe of the Perambulator, *or meaſuring wheel.*

THIS inſtrument, as it is now made, conſiſts of a light wooden wheel ſhod with a thin iron ring, the outſide circumference whereof is 99 inches, or half a ſtatute pole; a frame of wood of about three feet long, including the handle and the two cheeks, between which the wheel moves; alſo a box of about 10 inches diameter, containing a motion work; on the face whereof are three circles, and their indexes or hands; a revolution in the ſmalleſt circle anſwers to the length of one gunter's chain, a revolution in the greateſt circle anſwers to one mile, and a revolution in the other circle anſwers to 50 miles. The circle of one chain is divided into 100 equal parts, ſhewing the links; that of one mile is divided into 320 equal parts, ſhewing the poles; and the other circle is divided into 50 equal parts, ſhewing the miles: So that the meaſure of any diſtance, run over by the wheel, will be expreſſed in miles, poles, and links.

The motion of theſe indices is produced by the rotation of the wheel, whoſe axis, as it revolves, communicates motion to the work in the box through a groove or channel cut in one of the cheeks.

The length of the inſtrument, from the extremity of the wheel to the handle, is about four feet and a half; and its weight is about twenty-three pounds, the wood work being of mahogany, and the mo-

tion work of braſs: But it may be made much ſhorter and lighter.

To uſe the perambulator in the meaſuring of diſtances.

Being well aſcertained of the accuracy of each part of the inſtrument, open the lid of the box, ſet all the hands to the mark 0, or beginning of their reſpective circles, and ſhut the box; then taking the handle in both hands, drive the wheel before you, directing it towards ſome fixed point; when the propoſed diſtance is run over, obſerve the poſition of each hand, and theſe being rightly eſtimated, will give the meaſure of that diſtance, reckoning always from the point on which the wheel reſts, at the beginning and end, or the point perpendicularly under the axle.

To find the diſtance run over; obſerve, firſt, the mile index; ſecondly, the pole index; and, thirdly, the link index: If the mile index has not moved one diviſion, the diſtance is leſs than a mile; then the pole index will ſhew the whole poles, and the link index ſhews the links above the even poles: But, if the mile index has moved one or more diviſions, the diſtance run will be ſo many miles, and the overplus poles and links will be ſhewed by their reſpective indices.

Example I. Suppoſe the mile index ſtands between the beginning of its diviſions and the firſt mark; the pole index at 221; and the link index at 0; then the diſtance run over will be 221 poles, or 55 chains and 25 links, or 5 furlongs and 21 poles.

Example II. Suppoſe the mile index ſtands between the 3d and 4th diviſion; the pole index between the 184th and 185th diviſions; and the link index

index at its 67th diviſion; then the diſtance run over will be 3 miles, 184 poles, and 17 links; the other 50 links being equal to 2 poles, are accounted for in the pole circle.

When you have ſeveral ſucceſſive lines to meaſure, or one great diſtance, in the rout of which the intermediate diſtances of ſeveral places are to be noted; the three indexes may be ſet at the beginning of their reſpect circles, at the commencing each new line or diſtance; or, which is the better way, do not ſet the indices anew, but let them continue to revolve, and note at each diſtance the numbers ſhewn by the indices; and thus the whole diſtance paſſed over in any given time will be at once ſhewn; then the intermediate diſtances, which were noted, will be found, by ſubtracting the numbers entered in the field-book from one another.

To this inſtrument may be annexed two iron rods, which may lie cloſe under the cheeks, and when wanted may be let down and ſerve as legs, like thoſe of a wheel-barrow: Alſo to the cheeks may be fixed two ſtandards, which reaching above the wheel may ſupport a croſs piece, whereon a Theodelite, or other ſurveying inſtrument may be fixed, whoſe centre ſtanding over the axle-tree, will always correſpond to the place where the line begins, and, conſequently, the trouble of ſetting the head of the three legged ſtaff over the ſtation-ſtaff hole, will be avoided; beſide which, a ſurveyor uſing ſuch an inſtrument, will be benefited in the following particulars.

The tireſome repetition of ſtooping with the chain or pole, will be avoided.

In the trouble of handling the arrows, their account, and the difficulty of ſticking them into hard gravelly or rocky ground, or into the ground when frozen.

The expence of one, or both chain-men will be ſaved.

There can ariſe no ſuch errors as frequently happen to the chain, ſuch as its ſwaying, yawing, the difference of pricking down the arrows, or the diverſity in the lengths of chains.

The length of a days journey may be meaſured without keeping any account, till the end.

In taking the angles of elevation or deſcent, the Theodelite always ſtands at the ſame height from the ground.

A ſurveyor with one or two aſſiſtants, and this inſtrument, can meaſure any quantity of land in about half the time he could do it in by any other means.

To the uſe of this inſtrument it may be objected, that in going over many plough ridges, or ant-hills, there will be a conſiderable difference in the lengths given by the chain and wheel; there will, indeed, be ſome difference, and rather more than will happen in meaſuring the ſame diſtance forwards and backwards by the chain; for, by a trial on a common full of large ant-hills, in the moſt uneven part thereof, the wheel gave a pole more than the chain, in the length of a quarter of a mile, and going over more than 100 hills; and in meaſuring this length back again, the wheel gave the ſame diſtance; but the chain gave near half a pole more

than before: Beſides, an experienced artiſt would avoid taking the worſt place.

With regard to the objections concerning the paſſing of rivers, ponds, woods, brakes, &c. they are of ſmall import; for a perſon of any ſhare of ſagacity, will readily know how to proceed on ſuch emergencies.

With regard to the paſſing of hedges, ditches, gates, &c. and without varying the indices; theſe are eaſily anſwered; for by haſping the wheel, a contrivance to do this being provided, the indices are fixed; and the weight of the whole, though increaſed by the Theodelite, will not much exceed thirty pounds: But they may be made much lighter; and may be ſo contrived, both frame and wheel, as to take to pieces for the convenience of carriage, and packed up in the ſpace of little more than a cubic foot.

SECT. XV.

The uſe of the Univerſal Dial, and the variation of the compaſs.

IT has been ſuppoſed, that a needle, playing freely, which has had a ſtrong touch from the loadſtone, points exactly north and ſouth. But by numberleſs experiments it has been proved, That the needle does not point exactly north and ſouth, any where but in ſuch places on the earth as lie on one particular line, which is therefore called, *The Line of no Variation*; and this line is found to change its ſituation by a ſlow motion, from eaſt to weſt. It now paſſes from the weſtward of the *Cape of Good Hope* to the *Weſt-Indies*. And the variation of the needle in all other places is known conſtantly to alter by a ſlow change. In *England* that end of the needle which has been ſuppoſed to point full north, deviates from it now about 14.* degrees to the weſtward; and is ſtill, and alſo will for many years continue to increaſe, even till it arrive at its *Maximum*; and then will decreaſe till it vaniſhes, and then change to the eaſtward, as it formerly was; and by an oſcillatory change will ſo continue to alter.

This variation of the needle would no ways hinder the exactneſs of the ſurvey, if it was conſtant; nor is the alteration of the variation capable of mak-

* In the year 1749, the deviation to the weſtward was about 17 degrees.

ing

ing any ſenſible error in a ſurvey that is performed in a ſpace of time not exceeding four or five years.

But if the quantity of the variation be not known, and conſequently not allowed for, the north point of the compaſs, which the ſurveyor draws on his map, will err as much as that variation is. It is therefore convenient in all places to find it; and this may be done ſeveral ways: But by none more readily, more eaſily, or more exactly, than by the univerſal dial, as now made by Mr. HEATH, the inſtrument-maker mentioned before, the figure whereof is in the plate fronting the title.

This dial conſiſts of four principal parts, *viz.* the *Foot* or *Pedeſtal*, the *Meridian*, the *Equinoctial*, and the *Bridge*.

The *Pedeſtal* contains a box and a needle, and two croſs levels; whereby, with the help of the three ſcrews in the foot, it may be placed truly horizontal; and while the pedeſtal remains in this ſituation, the box and the circles of the inſtrument may be turned round to acquire a proper poſition of the meridian. The circumference of the box is divided into 360 degrees, and within this is another circle divided into four quadrants, and each numbered with 90 degrees. On the plane of that part of the pedeſtal which is moveable are ſegments of circles, containing a table of the equation of time; ſhewing the months, and days of the month, together with the minutes which watches, or equal time-keepers, are too faſt or too ſlow for the motion of the ſun: And on the outer margin of this moveable part, is a circle divided and numbered, either into 360 degrees, or into four quadrants, containing 90 degrees each; beginning with 0 degrees, at two points diametrically oppoſite: This circle ſlides againſt the fixed ring of the pedeſtal, on which is a *Vernier*'s ſcale, (commonly called *Nonius*'s) for obtaining parts of degrees.

The two ſcrolls which ſtand upright on the plane of the pedeſtal, and ſupport the rings of the inſtrument, have fixed to them a ſtrong ring, whoſe plane is at right angles to the diviſion 0 degrees on the plane of the pedeſtal; within this ring ſlides the *meridian*, on one ſide whereof are engraved the names of places, with their latitudes; and the other ſide is divided into four quadrants of 90 degrees each: To the upper part of the ring, within which ſlides the meridian, is fixed an index, on which is a *Vernier*'s ſcale, ſerving to ſhew the parts of degrees on the meridian; and to this piece is fixed a ring, by which the whole inſtrument may be lifted.

Concentric within the meridian is the *equinoctial* ring; having on one ſide the names of ſome places with their latitudes; on the other ſide the hours of a day, each divided into every ſecond minute; and the inſide of the ring divided in the ſame manner. This ring turns on two points diametrically oppoſite, fixed at the diviſions XII and XII, and the ſame points are fixed on the inſide of the meridian ring, againſt the diametrical diviſions 0 and 0. The equinoctial ring turning on theſe points, may be ſhut up within the meridian ring, or ſet at right angles to it, beyond which poſition it is not ſuffered to paſs, there being two pieces fixed to the meridian which ſtops the equinoctial ring when in the ſaid poſition.

The *Bridge* is a ſtrait flat piece, ſo fixed to the meridian ring as to turn on two points in the direction of the middle of the bridge, and oppoſite to the diviſions 90 and 90 on the meridian. On one ſide of the bridge are the names of the months, with diviſions to every ſecond day; on the other ſide are the ſigns of the Ecliptic, with their diſtances graduated to every ſecond degree; alſo the degrees and half degrees of declination, north and ſouth; and in the middle of the bridge is a ſlit, in which is placed a ſlider, with a hole in its middle.

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When an obſervation is made with this inſtrument, the latitude of the place counted on the meridian according as it is north or ſouth, diſtinguiſhed by N. and S. muſt be brought to the index at top; the ſlider on the bridge muſt be brought to either the day of the month, the Sun's declination, or the Sun's place, and then it will accordingly ſhew the other two: The equinoctial circle muſt be thruſt out of the meridian, till it is at right angles to it. Then bring the beginning of the degrees on the horizontal part of the pedeſtal to the index there: Turn the whole about upon the three feet, till the Sun ſhines equally on both faces of the plane of the meridian, the north part of the inſtrument being towards the north part of the world, and ſet the horizontal plane level. Then ſhall the dial be duly rectified for obſervation.

It may be readily known when the plane of the meridian is directed to the Sun's centre, by holding a piece of clean paper behind the meridian, and obſerving that the ſhade of the fore part of the ring falls juſt on the breadth of the inſide of the back part; and that the ſhade on the paper is of the ſame breadth with the thickneſs of the ring.

Now keeping the three feet in the ſame place, turn the dial about, till the ſpot of light paſſing thro' the hole in the ſlider, falls on the circle which is divided into hours, *&c.* in the middle of the inſide of that ring which repreſents the equinoctial; which will be among the morning hours, if before noon; and among the evening hours, if after noon; then will the dial ſhew theſe following very uſeful and pleaſant problems.

I. The ſpot of light points out exactly the hour of the day.

II. The circle repreſenting the meridian, lies exactly in the plane of the celeſtial meridian; and ſo a thread ſtretched over either face of it, draws a true meridian line.

III. The middle of the bridge points exactly to the true poles.

IV. The needle in the box ſhews the variation by the diſtance of its end from the beginning of the degrees there mark'd; and is weſtward, if the north end of the needle be to the left-hand of the beginning of thoſe degrees, but eaſtward when to the right.

V. The index on the horizon, points out the Sun's *Azimuth*, which is to be reckoned from eaſt or weſt, if the circle on the horizontal plane is divided into four nineties.

VI. Turn the meridian about the plane of the horizon, till the Sun ſhines equally on both its faces as at firſt, the three feet ſtill ſtanding in the ſame place, and move the meridian towards or from the Sun, till the ſpot of light coming thro' the hole in that ſight which has the croſs hairs in it, falls exactly on the little hole in the other ſight which will then be undermoſt; and the index in the *Zenith*, points to the Sun's altitude, among the diviſions of the meridian.

By this inſtrument, may the poſition of any wall be thus found: Let a ſtrait broad ruler, whoſe ſides are parallel, be applied to a wall, on which a vertical dial is deſigned to be drawn, and the two feet of the dial mark'd A, A, be applied to the other edge of the ruler; then let the dial be rectified to the latitude of the place, with the day of the month;

be

be levelled, and the upper part of the inſtrument turned about till the ſpot of light fall as before; then the index on the horizon will give the ſituation of that wall, uſually called by diallers, The declination of the plane. Or, if the Sun does not ſhine, apply the legs A, A, to the ruler, keep them in that poſition, and turn the upper part about, till the north end of the needle points at the variation; and then will the index on the pedeſtal ſhew the ſituation.

This curious inſtrument is of great uſe for the regulation of clocks and watches, by the help of the apparent time obſerved by it (as ſhewn above) and the equation of time engraved on the horizontal part of the pedeſtal.

It is alſo a very ready inſtrument for ſeating an horizontal dial duly: For after the apparent time is found by it, and the horizontal dial ſo ſeated, that it may be turned about, and ſtill be parallel to the horizon; then move it round, the Sun ſhining thereon, till it ſhews the ſame hour that the univerſal dial ſhews, and then it is truly placed, and may be there fixed to the pedeſtal.

And becauſe the latitude of the place where the inſtrument is uſed, muſt be known; there is engraved on the backſide of the meridian, or the underſide of the pedeſtal, the latitudes of the cities, and moſt remarkable towns in *England*, and other parts of *Europe*.

But if any gentleman pleaſes to communicate to the workman, the latitudes of his country ſeats, they may be particularly laid down on it.

Or if any gentleman about to travel, is pleaſed to communicate the tour he deſigns to take, he may have a catalogue of the towns in his way, and their latitudes, from Mr. *Heath*, with the inſtrument, in order to eaſe him of the trouble of ſearching maps, globes, or geographical books.

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The variation of the needle may be found by the *Theodolite*, thus: Take the bearing of the Sun exactly at 12 at noon, and the north-end of the needle gives the variation.

Or, take the bearing of the Sun, either at the time of riſing or ſetting; and then, ſay: As the ſine of the complement of the latitude, is to the ſine of the declination; ſo is the ſine of 90 degrees, to the ſine of the Sun's diſtance from the eaſt at riſing, and from the weſt at ſetting; and is always ſouther-ly, when the declination is ſouth, and northerly when north. And as much as this diſtance differs from that obſerved by the inſtrument, ſo much is the variation: And if the bearing taken by the inſtrument be to the left-hand of that calculated, it is weſterly, otherwiſe eaſterly.

Or it may be found, by an horizontal dial, duly ſeated, without the Sun; if you ſtretch a thread on that dial's meridian line, and the inſtrument placed near it, you turn the index about, till the teleſcope is parallel to that thread; for then the bearing ſhewn by the north-end of the needle, is the variation.

Beſide the preceding uſes of this univerſal dial; it may, with a very ſmall addition, be applied in all reſpects as a *Theodolite*, or *Circumferentor*; or this dial may be aptly and eaſily mounted on a *Theodolite*, and be taken off at pleaſure.

There is one inconvenience uſually attends the uſe of theſe inſtruments, which in this may be remedied: From about an hour before, to an hour after noon, the paſſage of the ſpot of light over the equinoctial, forms with it ſo acute an angle, that it is not very eaſy to obſerve the point where it croſſes it; and, conſequently, the preceding problems cannot be ſo exactly performed. And juſt at noon, the thick-

neſs

neſs of the braſs ſhades the ſlider and bridge; and ſo no obſervation at all can be made.

In this caſe, bring the beginning of the degrees to the index on the horizontal part, and let the hour be taken by the inſtrument ſome time before, which is remote from noon, whether before or after, on the board of the window of your ſtudy, where you deſign to uſe it; the index all the while pointing to the beginning of the degrees. Lay a ſtrait ruler to touch the feet marked A, A; and by its edge, draw on the window-board a ſtrait line, or make two points where that ſtrait line ſhould be drawn: And then, at any time that is very near noon, by laying the ruler to the line or points, bringing the beginning of the degrees on the horizontal part of the pedeſtal to the index, and applying the feet A, A, to the edge of the ruler, as before; if you rectify the inſtrument to the latitude and day, you may ſee the true time either before or after noon; and juſt at noon, the middle of the under part of the meridian will be ſhaded by the upper; and conſequently the time of noon, is known, and determined, whether it be before or after noon.

If you are in a ſtrange place, and the time be very near noon, level the inſtrument, and turn it about till the north-end of the needle points at the variation, and then it is duly placed, and you may work as in the laſt.

Much more might be ſaid of this inſtrument's uſe, but my deſigned brevity will not permit me to enlarge any farther thereon.

The latitude of a place may be found by the common Theodolite, thus: Turn the plate of the inſtrument ſo that it be in a vertical poſition, in the plane of the meridian, which may be readily known by applying to the plate a ſtring and plummet; with this poſition, Set the fixed ſights horizontal, either by

by a level, or by the thread of a plummet cutting the degree at right angles to the fixed ſights; then a little before noon move the index ſo that the Sun's rays paſſing thro' the hole in one ſight, the ſpot may fall directly on the middle line of the other ſight; and the degrees cut by the index will ſhew the Sun's altitude at that time: As the Sun mounts higher, the ſpot will deſcend on the ſight, therefore keep the index moving ſo as to ſtay the ſpot on the line, until the ſpot be obſerved to begin to riſe above the line, then obſerve the degrees cut by the index, and they will be the meridian altitude, and their complement to 90, will be the Sun's zenith diſtance; which on this ſide the tropic of *Cancer* muſt always be named ſouth.

Now having the Sun's meridian zenith diſtance, and his declination taken from tables, the latitude of the place may be found by this

RULE. If the zenith diſtance and declination have contrary names, their ſum gives the latitude ſought, of the ſame name with the declination.

But, if the zenith diſtance and declination have the ſame name, the difference will be the latitude ſought, of the ſame, or a contrary, name with the declination, as it is greater, or leſs, than the zenith diſtance.

SECT.

SECT. XVI.

The deſcription and uſe of the Pantographia, *or* Imitator.

THIS inſtrument conſiſts of four rulers, two large and two ſmall: The two great ones are joined at one of their extremities by a joint, or centre, about which they are eaſily moveable. At the bottom of this joint is a little roller or caſter, whereon the inſtrument is to bear: One end of each of the two ſmall rulers are pinned near the middle of each great one, and the other ends faſtened by a joint, ſo that in what manner ſoever the inſtrument is moved, the four rulers always form a parallelogram, having two contiguous ſides about as long again as the other two ſides.

The two longer, and one of the ſhorter rulers have each a box fitted to them, that may be moved and fixed to any part of the ſaid rulers, by means of a ſcrew fixed to the box. Theſe boxes have each a cylindric hole, wherein may be alternately put three things; namely, a tracing-point, a port-crayon, that riſes and lowers of itſelf, according to the unevenneſs of the plane worked upon; and, a fulcrum that ſcrews into the table, the top whereof is a cylinder fitting one of the boxes: This fulcrum is the fixed point round which the inſtrument moves, when uſed to copy with. There are alſo other caſters on which the rulers reſt, ſerving likewiſe to facilitate their motion. On theſe rulers are diviſions with figures, ſhewing where to place the

chamfered, or bevel edge of the boxes, according to the intended reduction.

This inſtrument is convenient for ſuch who are converſant in the art of drawing, as well as for thoſe who have made but little progreſs therein; for with it, may be neatly taken, with great eaſe and accuracy, the copies of all manner of deſigns, whether figures, ornaments, plans, geographic carts, and ſuch like, reducing them from a larger ſize to a ſmaller, or from a ſmaller to a larger. The references in what follows is in plate VII, where the three boxes are marked by the letters A, B, D.

To uſe the Pantography.

Firſt, Having determined the proportion that is to be between the original and copy, ſet the bevel edge of the boxes B and D to the diviſion expreſſing that proportion, there ſcrew them faſt; and fix the edge of the box A to the line C.

Second, Screw the fulcrum into ſome convenient part of the board on which the operation is to be performed.

Third, Put the fulcrum into the hole of the box B; the crayon into that of D, and the tracer into that of A, when the copy is to be leſs than the original; but when larger, put the crayon into A, and the tracer into D.

Fourth, Open the inſtrument ſomewhat, fix the original under the tracer, and clean paper under the crayon; then, while a ſteady hand moves the tracer over the lines of the original, the crayon or pencil will draw the copy required.

The diviſions or ratios thought proper to be placed on the rulers B and D of this inſtrument, are $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, $\frac{1}{6}$, $\frac{1}{7}$, $\frac{1}{8}$, $\frac{1}{9}$, $\frac{1}{10}$, $\frac{1}{11}$, $\frac{1}{12}$; and $\frac{2}{3}$, $\frac{3}{4}$, $\frac{4}{5}$, $\frac{5}{6}$, $\frac{6}{7}$, $\frac{7}{8}$, $\frac{8}{9}$, $\frac{9}{10}$, $\frac{10}{11}$, $\frac{11}{12}$; theſe numbers denote the propoſed ratios between the copy and original; thus, if the copy is to be half the length and breadth of the original, the boxes B, D, and A, are to be ſet at the diviſions $\frac{1}{2}$ and C; then the fulcrum is to be put into B, the crayon in D, and the tracer into A: If the length and breadth of the copy is to be $\frac{3}{4}$ of thoſe of the original, the boxes B and D are to be put to the diviſions $\frac{3}{4}$, the box A, remaining at the mark C, where it is to be ſet in every operation; the fulcrum to be put into D, and the crayon into B. And in like manner any other diminution, within the limits of the diviſions, may be readily performed.

When the copy is to be increaſed in any ratio expreſſible by one of theſe numbers, the boxes B and D are to be ſet to that number as before; the fulcrum put in B, the tracer in D, and the crayon in A; then the picture being put under the tracer D, and the clean paper under the crayon A, the copy may be taken as before.

When the copy is to be of the ſame ſize as the original, fix the bevel edge of the boxes B and D, to the marks $\frac{1}{2}$, and the box A to the mark C; put the fulcrum into the box D, the crayon into B, and the tracer into A; then will the crayon B move over equal lines and ſpaces with the tracer A, and, conſequently, delineate a copy equal in ſize to the original.

And thus may any picture be accurately copied without damaging it in the leaſt; for the tracer may be paſſed over the lines without preſſing on them, or even touching them: But that this buſineſs of copying may be rendered as perfect as can be deſired, it will be neceſſary to be more circumſtantial

in

in deſcribing the uſe of this inſtrument, particularly ſome appendages and cautions not yet mentioned.

In *plate* VII. *fig.* 1. repreſents the plan of the inſtrument, with all the diviſions; figure 2 is a perſpective view of it on a table, in the proper poſition for uſe. The boxes A, B and D are placed for reducing the original to one third of its ſize, or as 1 to 3, ſhewn in the figure. The fulcrum I, ſcrewed into the table, is placed in the box B; this fulcrum, as hitherto deſcribed, is fixed, but a moveable one may be ſubſtituted in its room, as ſhall be ſhewed hereafter.

Over fig. 2, the different pieces fixed to the rulers are ſeverally repreſented. The figures A and B repreſent the two boxes. E is the tracing point that fits in the ſocket N, fixed to the boxes A and B. Theſe ſockets has a little ſcrew O, ſerving to fix the tracing point when ſet in the boxes, at the proper height.

Figure F is the tube for the port crayon. G is the port crayon to be put into the tube F; it has a ſmall ſilken ſtring fixed to it, ſerving to raiſe the crayon or pencil, ſo that it may not touch the paper while it is moving from one place to another. This ſtring is thus uſed; when the crayon is in the box D, paſs the looſe end through the holes in the upright pieces fixed at Z, S, X, fig. 2; then taking the end into the hand holding the box A, the crayon may be raiſed with the greateſt eaſe, whenever it is wanted, even while the inſtrument is moving. But if the crayon is put into the box A, then the looſe end muſt paſs through the holes in the pieces X, S, Z, and ſo to the hand, which in this caſe will have hold of the box D.

The ſtring is repreſented in fig. 2. its length is always the ſame, however the boxes are placed, becauſe it follows the direction of the rulers.

The

The cup H above the port crayon G, ſcrews on its upper part, and ſerves to increaſe the weight of the crayon or pencil, making it preſs harder on the paper when neceſſary; this is done by putting in leaden ſhot, or any ſuch like weight.

The little wheel, or caſtor, L, that has a double ſlit or groove, x and y, is fixed to the ruler B by the under groove x, when the crayon is put into the box B. But if put into D, the caſtor or wheel L then ſlips on the ruler D by the upper groove y. M is a wheel or caſtor to be put on the ruler A.

The fulcrum, ſcrewing to the table, as mentioned in the foregoing deſcription, and repreſented in fig. 2, being proper only to copy ſubjects of a middling ſize; a moveable fulcrum repreſented by fig. P, is to be uſed when the picture is large. This fulcrum is a piece of lead of ſufficient weight to prevent its being diſplaced by the motion of the inſtrument. In the middle thereof is ſcrewed a pin K, like the fixed fulcrum I. The figure R is a little collar, ſerving equally to either the fixed or moveable fulcrum, on whoſe pin it is put when either of them is placed at the box D: But is not uſed when placed at the box B, becauſe this is leſs diſtant from the table. Little collars, of different heights, are alſo uſed in the ſame manner to K and I; the uſe thereof depending on the prudence of the operator, taking care that the motion of the inſtrument be performed with the utmoſt freedom.

With this moveable fulcrum a picture or drawing of any dimenſion may be copyed: For the picture being made faſt on any table or plane, the fulcrum muſt be ſo ſituated that a part thereof may be copyed as far as the inſtrument can extend at that time. Then on the picture and paper mark three correſponding points on each, to ſerve as references for finding the poſition of the fulcrum in the copy, relatively to what has been already drawn; move

the fulcrum towards the picture, and when the three points on each are found to correſpond, fix the copy in that ſituation with a little ſoft wax; then continue drawing as far as the inſtrument can extend, as before, repeating this operation till the whole is copyed.

The uſefulneſs of this moveable fulcrum is eaſily perceived; for if towards the end of the operation both the copy and fulcrum ſhould reſt on the picture, it would be no inconvenience as they no ways damage it. By this means alſo the extraordinary length of the rulers is prevented, which are generally but of about two foot and a half; a greater length would render them inaccurate, becauſe they would then be more ſubject to bend and ſpring.

It may happen, on account of the ſize of the paper, or otherwiſe, that the copy will not be in a proportion to the original, expreſſible by any of the diviſions on the inſtrument; in ſuch caſe a method muſt be found to do without, by placing the crayon, tracer and fulcrum in a poſition anſwering to the relative dimenſions of the original and copy.

In order to which it is neceſſary to obſerve, that the fundamental principle, on which depends the accuracy in operating by this inſtrument is, that the fulcrum, crayon, and tracer, are always to ſtand in a right line, in every poſition of the rulers; whenever they are ſo, the copy will truly repreſent the original. By the following method it will be known if thoſe three points ſtand in a right line.

Let the fulcrum, crayon, and tracer, be included between a doubled thread, as in the figures marked 1, 2, 3, ſtanding under the inſtrument marked fig. 1: Hold theſe threads faſt at the mark 3, and if the points are not in a right line, the thread will be bent at the box D, marked 2; this box muſt then be moved till the threads become parallel, by

touching both ſides of the three cylinders, which will then be in a right line.

This principle being obſerved in the poſition of the abovementioned points, let there be given a picture or drawing of any dimenſion to reduce to a ſize that is no aliquot part or parts of the original; then operate in the following manner.

Examine, firſt, if the given ſize is greater or leſs than half the original.

When leſs, always place the fulcrum in the box B, the crayon in the box D, and the tracer in A; theſe points being brought to a right line as beforementioned, run over with the tracing point A, the whole length or breadth of the original in a ſtrait line; then examine whether the line made by the crayon agrees with the ſize given.

If not, and that the ſpace run through by the crayon is leſs than the given ſize, bring the box B nearer to the line B on its ruler, and the box D nearer the line D on its ruler.

If, on the contrary, the line traced by the crayon be greater than the given ſize, bring the two boxes B and D towards the junction Z of the rulers B and D; and, by trials, the proper extent will be found.

By this method, a drawing of any dimenſion may be copyed on any given ſize, without regard being had to the diviſions on the ruler.

If the given ſize be greater than half the original, then the fulcrum muſt be placed in the box D, and the crayon in the box B.

When the picture is ſo large that the inſtrument cannot extend to its limits, then a third, fourth, *&c.* part may be taken, proportioning the parts of the copy to thoſe on the original; and working according to the foregoing directions, an accurate reduced copy thereof may be obtained.

To find the diviſions on the legs S B, S D.

Let the lines A B, A C, E G, G H, (*Fig.* 4. *Plate* VII.) repreſent four rulers, ſo connected together, that in any poſition of A B, A C, there may always be formed a parallelogram, whoſe ſides are A E, E G, G H, H A.

Now if A C is of any fixed length, and the ratios of A E and E D to A C be aſſumed, and thro' D be drawn the right line C D, meeting A B in B.

Required the length of A B.

Let A C : A E :: a : c. Then A E = $\frac{c}{a} \times$ A C.

And A C : E D :: n : m. Then E D = $\frac{m}{n} \times$ A C.

Now C F : F D :: E D : E B, by ſimilar triangles.

Or AC — ED : FD :: ED : AB — AE.

Then $AB - AE = EB = \frac{FD \times ED}{AC - ED}$.

Put AC = r. Then AE = $\frac{c}{a} r$; and ED = $\frac{m}{n} r$.

And $r - \frac{m}{n} r : \frac{c}{a} r :: \frac{m}{n} r : AB - \frac{c}{a} r$. Therefore

$$AB \times r - AB \times \frac{m}{n} r - \frac{c}{a} r\, r + \frac{m\,c}{n\,a} r\, r = \frac{m\,c}{n\,a} r\, r.$$

Therefore $AB \times r - AB \times \frac{m}{n} r = \frac{c}{a} r\, r$.

Conſequently $AB = \frac{n}{n-m} \times \frac{c}{a} \times r$.

Hence

Hence $AB = \frac{1}{2}r \times \frac{n}{n-m}$, when $AE = \frac{1}{2}AC$.

Alſo $AB = \frac{1}{2} \times \frac{n}{n-m}$, when $AC = 1$.

If the ratio of AE and AB to AC were aſſumed, to find ED.

Then $AB : AC :: EB : ED$.

Or $AB : AC :: AB - AE : ED$.

Let $AB : AC :: s : t$. Then $AB = \frac{s}{t}AC$.

And $\frac{s}{t}AC : AC :: \frac{s}{t}AC - \frac{c}{a}AC : ED$.

Or $\frac{s}{t}r : r :: \overline{\frac{s}{t} - \frac{c}{a}} \times r : ED$.

Therefore $ED = \left(\frac{sta - ttc}{sta} =\right) 1 - \frac{t}{s} \times \frac{c}{a} \times r$.

Hence $ED = 1 - \frac{t}{s} \times \frac{1}{2}r$, when $AE = \frac{1}{2}AC$.

Alſo $ED = 1 - \frac{1}{2} \times \frac{t}{s}$, when $AC = 1$.

And hence the numbers in the following table were found. Where ED in the firſt column, and AB in the third, are each compared to AC, their ratios being expreſſed by the numbers in thoſe columns; and the numbers in the ſecond and third columns, are related to AC as the unit; AE being ſuppoſed equal to $\frac{1}{2}$ AC.

A TA-

A TABLE for the diviſions of the Pantographer.

When E D is	Then A B is	When A B is	Then E D is
$\frac{1}{2}$	1,	$\frac{2}{3}$	0,25
$\frac{1}{3}$	0,75	$\frac{3}{4}$	0,3333
$\frac{1}{4}$	0,6666	$\frac{4}{5}$	0,375
$\frac{1}{5}$	0,625	$\frac{5}{6}$	0,4
$\frac{1}{6}$	0,6	$\frac{6}{7}$	0,4166
$\frac{1}{7}$	0,5833	$\frac{7}{8}$	0,4285
$\frac{1}{8}$	0,5714	$\frac{8}{9}$	0,4375
$\frac{1}{9}$	0,5625	$\frac{9}{10}$	0,4444
$\frac{1}{10}$	0,5555	$\frac{10}{11}$	0,45
$\frac{1}{11}$	0,55	$\frac{11}{12}$	0,4545
$\frac{1}{12}$	0,5444		

When the ratio of the copy to the original is found in the firſt column; the tracer is to be in A, the crayon in D, and the fulcrum in B, if the copy is diminiſhed; but, if increaſed, the tracer and crayon change places.

And if the ratio of the copy to the original is found in the third column, then the tracer is to be in A, the crayon in B, and the fulcrum in D, if the copy is diminiſhed; but if the copy is to be increaſed, the tracer is to be put into B, and the crayon into A.

F I N I S.

Fig. 1.

Fig. 2.

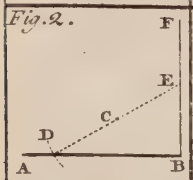


Fig. 3.

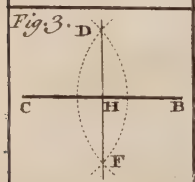


Fig. 4.

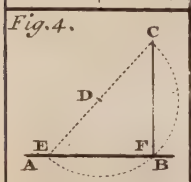


Fig. 5.

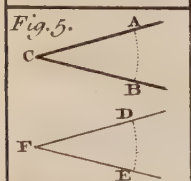


Fig. 6.

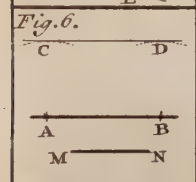


Fig. 7.

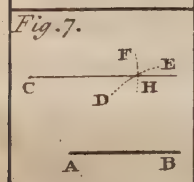


Fig. 8.

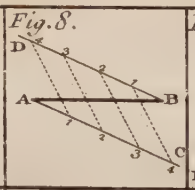


Fig. 9.

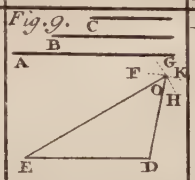


Fig. 10.

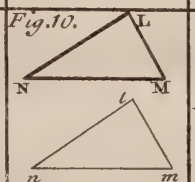


Fig. 11.

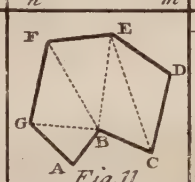


Fig. 12.

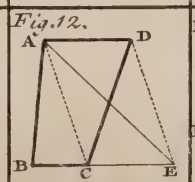


Fig. 13.

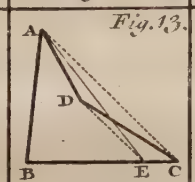


Fig. 14.

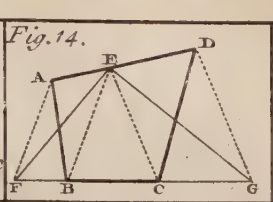


Fig. 15.

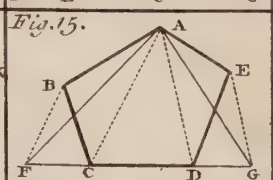


Fig. 16.

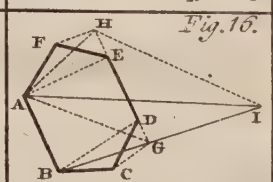
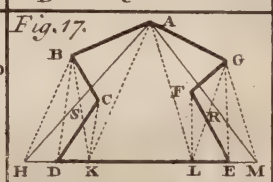


Fig. 17.



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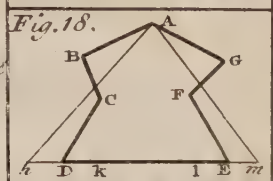

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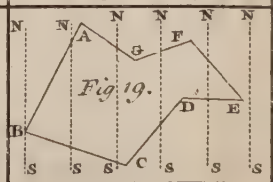

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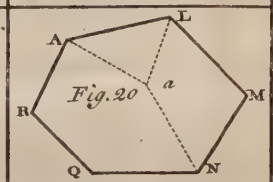

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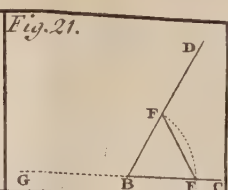

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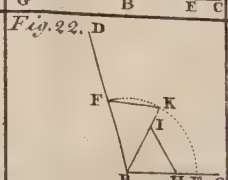

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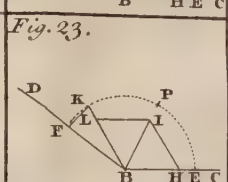

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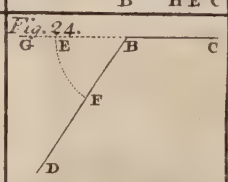

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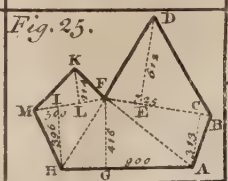

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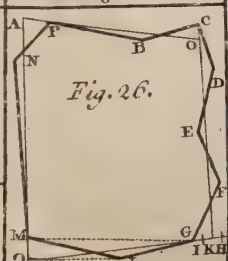

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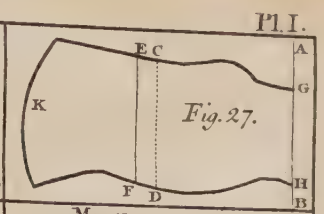

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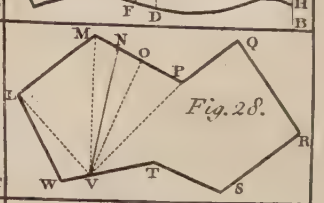

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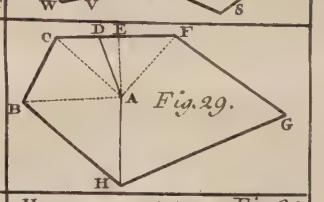

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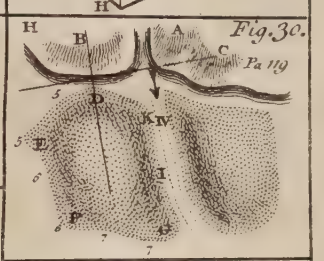
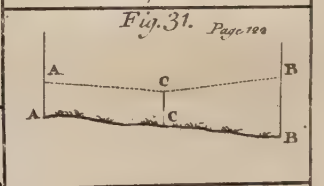


Fig. 31. Page 120



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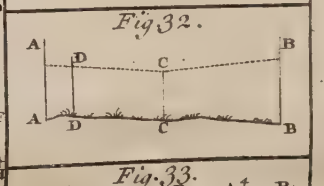
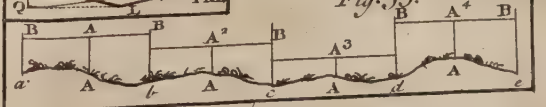
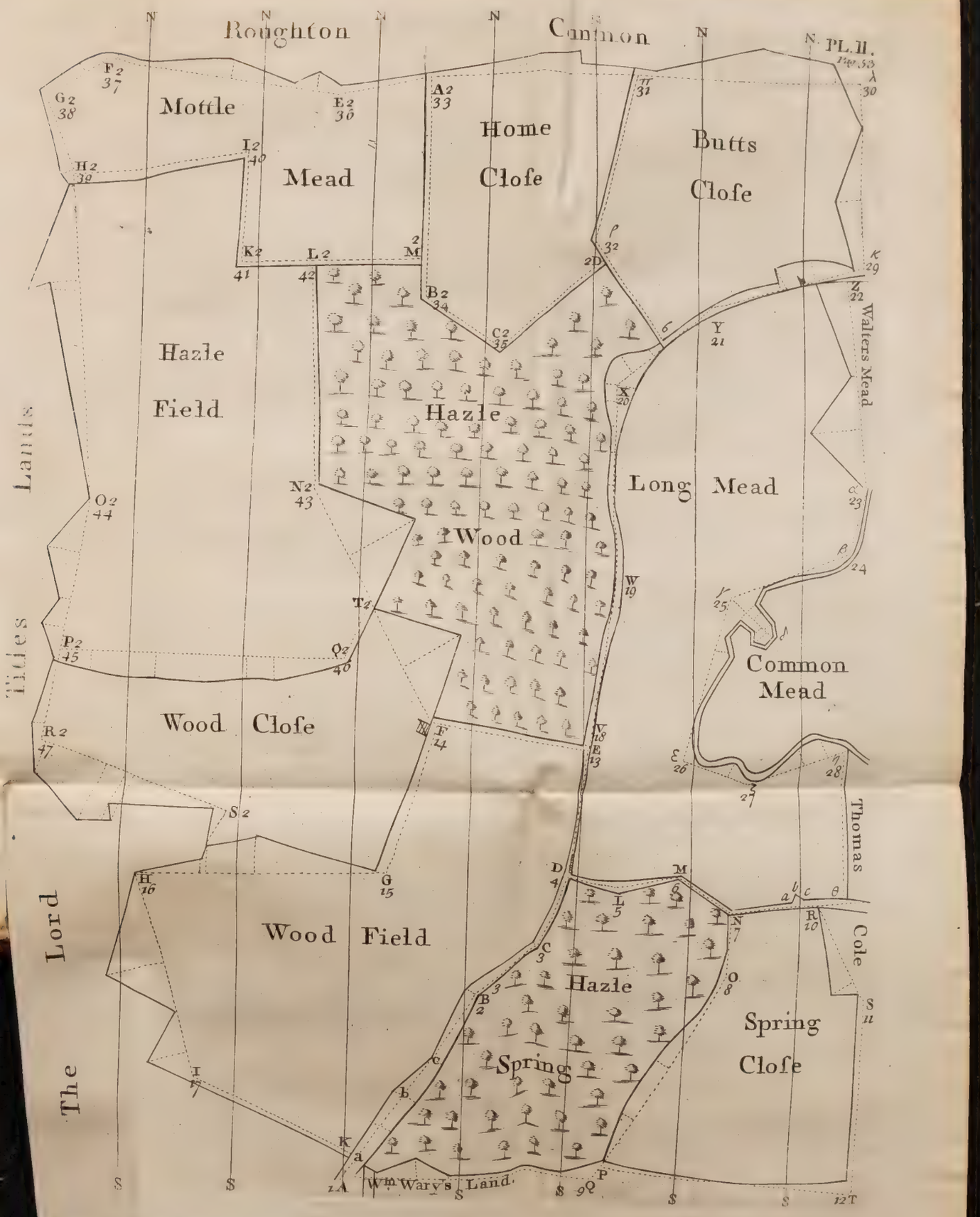


Fig. 33.

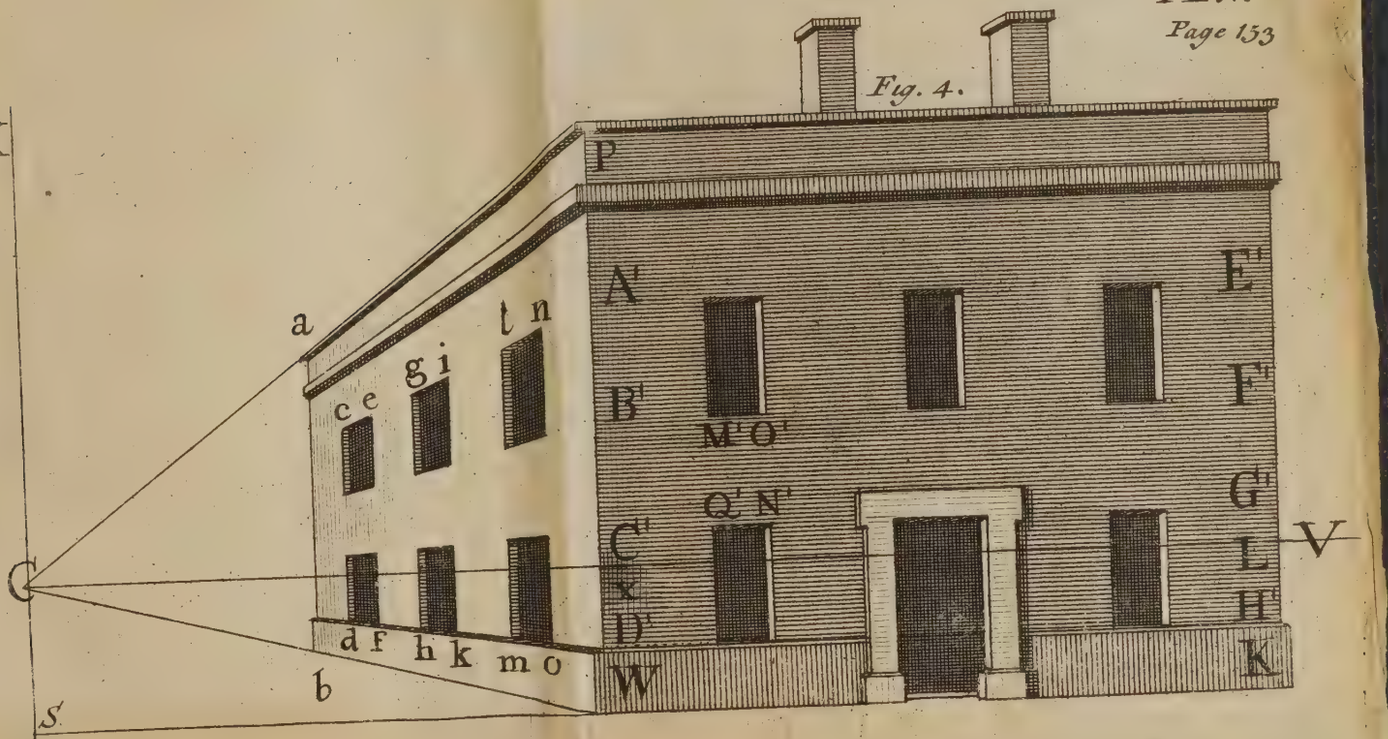


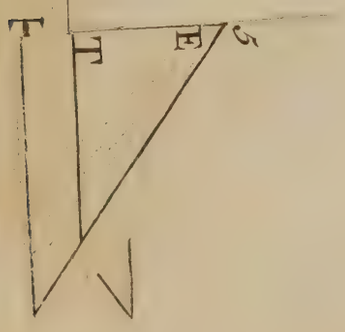

Roughton Common
PL. II.
Mottle
Home Clofe
Butts Clofe
Mead
Hazle Field
Hazle
Wood
Long Mead
Walters Mead
Common Mead
Wood Clofe
Wood Field
Hazle
Spring
Spring Clofe
Thomas Cole
The Lord Tides Lands
Wm Wary's Land.

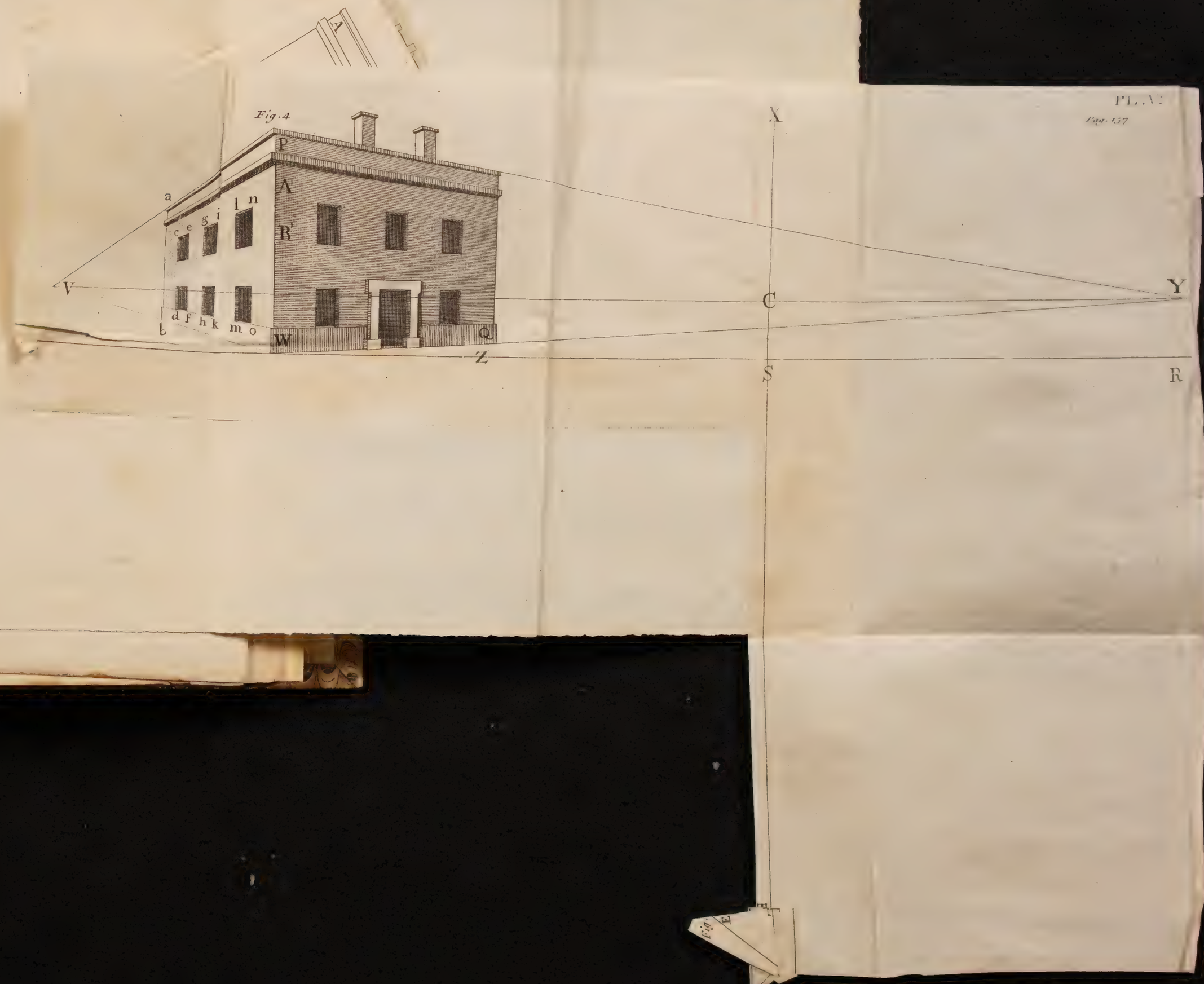
Plotted by a Scale of 3 Chains or 12 Poles to an Inch

PL. IV.
Page 115

Fig. 4.






A
Fig. 4
P
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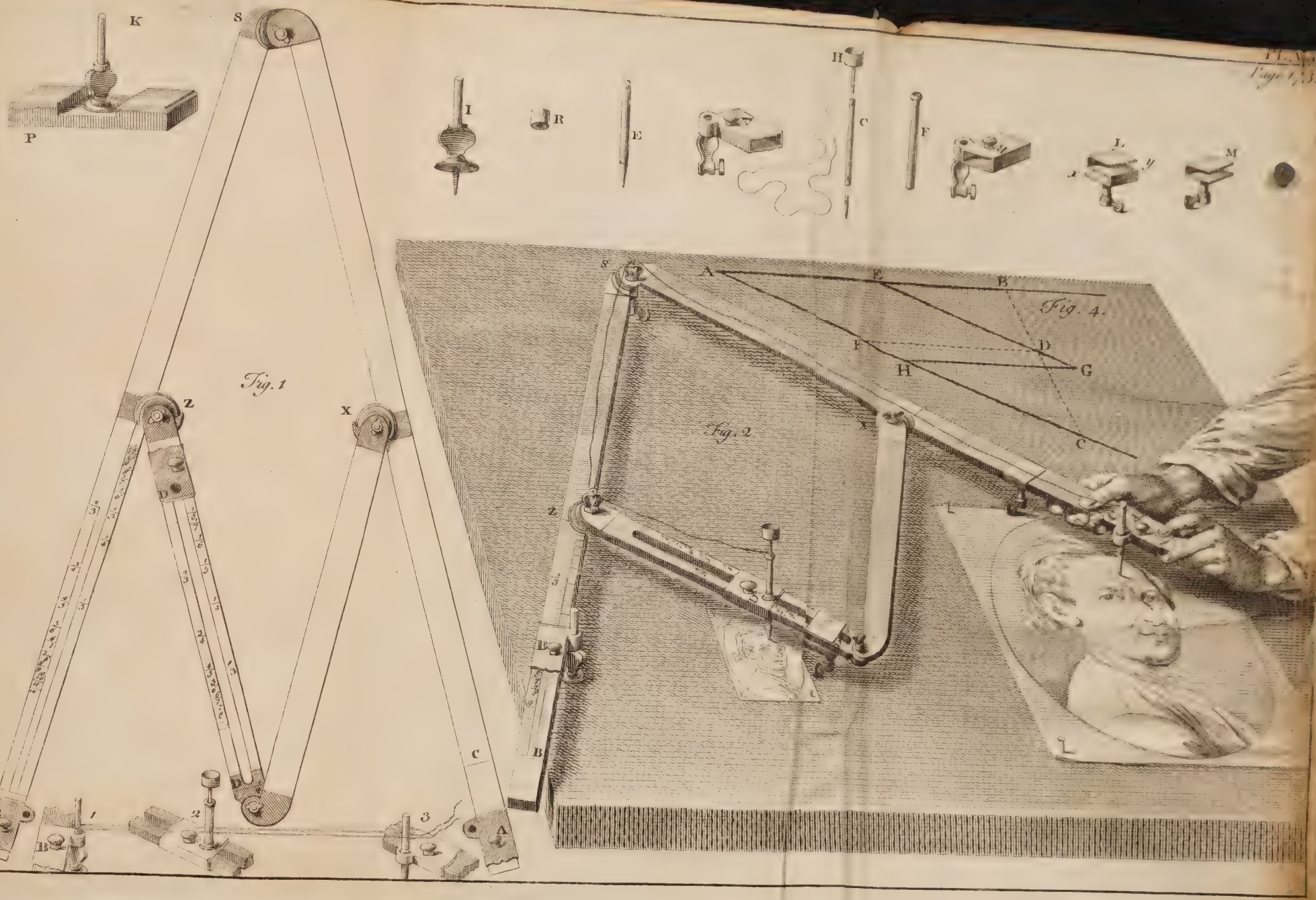
K
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Fig. 1
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Fig. 2
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Fig. 4